

INDIAN SCIENCE CONGRESS
ASSOCIATION.

Forty-Third Session,

Agra-1956

Part 2.

Presidential
Address.



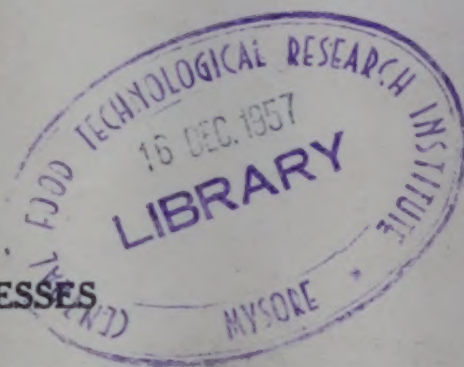
INDIAN SCIENCE CONGRESS ASSOCIATION

(Registered under Act XXI of 1860)

PROCEEDINGS OF THE FORTY-THIRD SESSION

AGRA-1956

PART II PRESIDENTIAL ADDRESSES



1, Park Street, Calcutta - 16



Proceedings of the Forty-third Indian Science Congress

PART II : PRESIDENTIAL ADDRESSES

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FORTY-THIRD INDIAN SCIENCE CONGRESS

AGRA, 1956

Congress President : DR. M. S. KRISHNAN, M.A., Ph.D., F.N.I.

PRESIDENTIAL ADDRESS

At the outset I wish to express my sincere thanks and gratitude to fellow members of the Indian Science Congress for the great honour they have conferred on me by electing me to the high office of President which has been occupied by a succession of men distinguished for their outstanding contributions to some branch of science or technology.

The Indian Science Congress has been in existence for 42 years. It is still vigorously growing as can be seen from the interest taken in its sessions not only by professional scientists, but also by the enlightened public. This interest is in some measure due to the encouragement given to scientific and technological research by our Government and particularly by our Prime Minister. The importance of science and technology to the material advancement of any country in the present age is wellknown and it is but proper that India should give increasing attention to research for being able to advance in various directions.

It looks to me that the time has come for making some important changes in the work programme of the Science Congress Sessions. In the olden days it was possible to read and discuss several papers in each section of the Congress but at present the amount of time available is strictly limited and much of it is taken up by symposia. The great majority of the papers submitted to the Science Congress are generally taken as read, and even if a few papers are taken up for reading, sufficient interest is not aroused in the discussions following the presentation. In my opinion it is now worth considering whether we should not stop accepting miscellaneous papers and concentrate on organising symposia on topics of special importance in which all the members of the sections concerned may take part. I am aware that this proposal is likely to be unpopular with a number of our memebtrs, but unless we do something like this we cannot carry on the pretence that the papers are submitted to the Science Congress for reading ; it will save the Science Congress considerable expenditure on printing if only summaries of the symposia and of the few important papers read are published.

You are all aware that three years ago the Corporation of Calcutta made a generous donation of land in that city for enabling the Science Congress to put up its own accommodation. The Government of India have since kindly agreed to contribute towards the cost of the building so that in about two years it will be possible for the organisation to carry on its work in its own buildings.

From the point of view of the scientists the most important event during the past year was the conference held at Geneva during the last summer on the peaceful uses of Atomic energy. Though India cannot yet claim to be in the forefront of research in the development of Atomic power, she played an important part in organising the conference and bringing together various countries of the world under the auspices of

the United Nations. It is to be hoped that in future we will hear less of uranium and hydrogen bombs and more about the development of Atomic energy for the production of electrical power for use in Industrial plants and in medical and agricultural research.

I shall now pass on to the subject of my address which will deal with mineral resources and their problems.

MINERAL RESOURCES AND THEIR PROBLEMS

MINERALS AND MODERN CIVILIZATION

It is generally known, but not fully realized, what important part minerals play in modern civilization. They provide the chief fuels and sources of power, *viz.*, coal, petroleum and natural gas. Modern transport, communications, mass production in diversified industries and many marvels of science are all closely connected with minerals. Many things we now take for granted, whether we regard them as necessities or luxuries—automobiles, steam and electric trains, ships, aeroplanes, radio, the various electrical and electronic devices and a large proportion of the countless products of the chemical industry—are all manufactured from minerals.

Many of the mineral products are so inter-related to each other and so essential to one industry or another, that it is no longer possible to say that one group of minerals is more important than the other. The metals and their innumerable alloys are indispensable for many ordinary and special uses to which they are put. Without them many modern chemical and metallurgical processes would be impossible, as the latter require materials to withstand extreme conditions of temperature pressure, corrosion, acidity, etc. The metallurgical industry depends in its turn on the availability of a variety of refractories or heat-resistant substances with which furnaces are lined and containers made. The machinery and appliances used in the generation and transmission of electricity depend on the conductive properties of metals and on insulating materials like mica and special porcelain which prevent the leakage or loss of electricity. The shaping, cutting and polishing processes depend on a group of minerals called abrasives, whose utilisation is dependent on their hardness and toughness; the best known amongst these being diamond, corundum, emery, garnet and different forms of quartz. There are others which are used as protective coatings on metals, wood and other materials of construction to prevent rusting, corrosion and deterioration, these being included in the group called paint pigments. Still others, because of their brilliant colour, lustre and hardness, are used as ornaments—precious and semiprecious stones.

From the very dawn of human civilisation *i.e.* from the time when man began to develop intelligence to counter nature's vagaries and conquer her forces, he has used mineral products, a few at first and more as time went on. The earliest materials to be used must have been stones for building shelters, flint and quartz for making implements and ochres for ornamenting dwellings and the human body. Then followed the use of plastic clay for making pots and utensils. Naturally occurring metals like gold, silver, copper must have attracted attention when found, for they were not only bright and lustrous but possessed malleability and ductility and the power to retain their lustre. Between that stage and the discovery of the smelting of iron, a long period of time

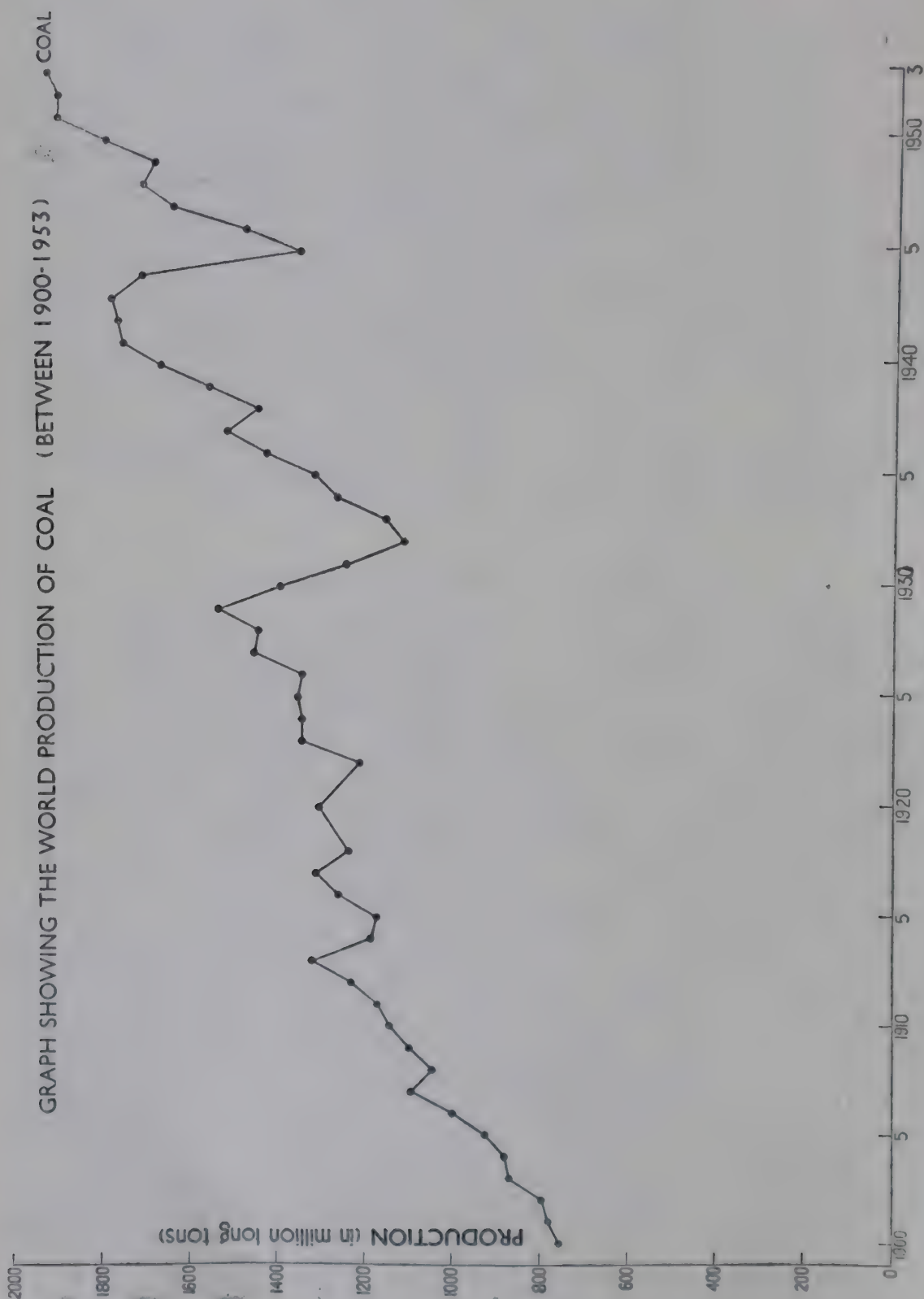
must have elapsed. In due course the smelting of a few other metals would have followed, these metals occurring mostly as easily reducible oxides and sulphides. A high stage of civilisation had already been attained by the time iron and bronze became available in large quantities as fairly common metals. We have no reliable records as to when iron was first manufactured in India, but it was probably not less than 3500 years ago. Even in the 13th Century B.C. it was comparatively a rare commodity in the Levant and Egypt, for there are authentic archaeological records to show that the smelting and production of high quality iron was then known to the Hittites of Asia Minor (who were an Indo-Aryan race) but practically unknown to the Egyptians. The inference that may be made from this is that the Hittites probably got their knowledge from their kinsmen in India or Iran. J. M. Heath, the pioneer in modern blast furnace manufacture of iron in India more than 120 years ago, has expressed the view that the use of iron in India predated the use of bronze and that the Egyptian pyramids must have been built with the aid of iron implements imported from India or made with the knowledge derived from India. The earliest iron objects known in India are those found in the excavations made for the foundations of the Bodh Gaya temple which are probably of the 4th Century B.C. The iron implements found in pre-historic burial sites in the Tinnevelly district of Madras may be several centuries earlier. The famous Delhi iron pillar which is usually attributed to the 4th Century A.D. by archaeologists is much later, though the most celebrated. Iron was certainly an important article of trade, albeit for military purposes, in the first millennium before Christ, when the availability of horse chariots and iron weapons determined the fate of empires.

RAPID INCREASE IN THE USE OF MINERALS

Even at the dawn of the industrial revolution in Western Europe, which followed the invention of the steam engine, only a few mineral products were used. These were iron, copper, lead, zinc, tin, gold, silver, mercury, precious stones, sulphur, clays and building stones. Many metals, non-metals, alloys and chemicals were still laboratory curiosities. Those metals which could be easily reduced from their ores by the use of charcoal or coal were the first to be made and used. The commercial production of aluminium, though it is one of the most abundant metals in the earth's crust, had to wait until the development of the electric furnace barely 125 years ago. About a hundred years ago, aluminium was in the same stage of development as titanium has been during the last decade. And even now the chief ore of aluminium is bauxite and not common clay which is one of the most abundant substances in the external part of the crust of the earth. Magnesium metal was isolated about 140 years ago but did not have any major use until after the first World War. Titanium which is one of the more common elements in the earth's crust has been manufactured on a fairly large scale only during the last decade, because of the many technical difficulties which its metallurgy presents. Beryllium, which is the other light metal, will probably never become a major metal because its chief ore, beryl, is comparatively scarce and is unlikely to be produced in very large quantities.

It is well known that mankind has used more metals and minerals during the present century than during all its long civilised existence. Modern industry is expanding at an ever-increasing pace, as almost every country is now bent upon industrialisation and the already industrialised

countries are steadily expanding their activities. This will be evident from the output of a few typical metals and minerals during the current century shown in the accompanying graphs (See Figs. 1 to 6). The graphs are, however, not even because of the fact that the two world wars stimulated sudden and extraordinary increase in production, followed by depressions, during which the output fell below the normal levels. This is particularly noticeable in the graphs for metals.



Minerals differ from other natural resources in certain important respects. We find them sparsely and sporadically distributed and they are wasting or non-renewable assets. The products of the animal and vegetable kingdoms are renewable seasonally or annually—not so the minerals. Under certain exceptional conditions, supplies are replenished quickly—*e.g.* sulphur in areas where volcanoes are active. But geological processes, sedimentary or igneous, generally take a very long time to produce any appreciable results. They would be of no use even if we are prepared to wait for a century or two, but they may really take many millions of years to yield worthwhile results! Many mineral deposits

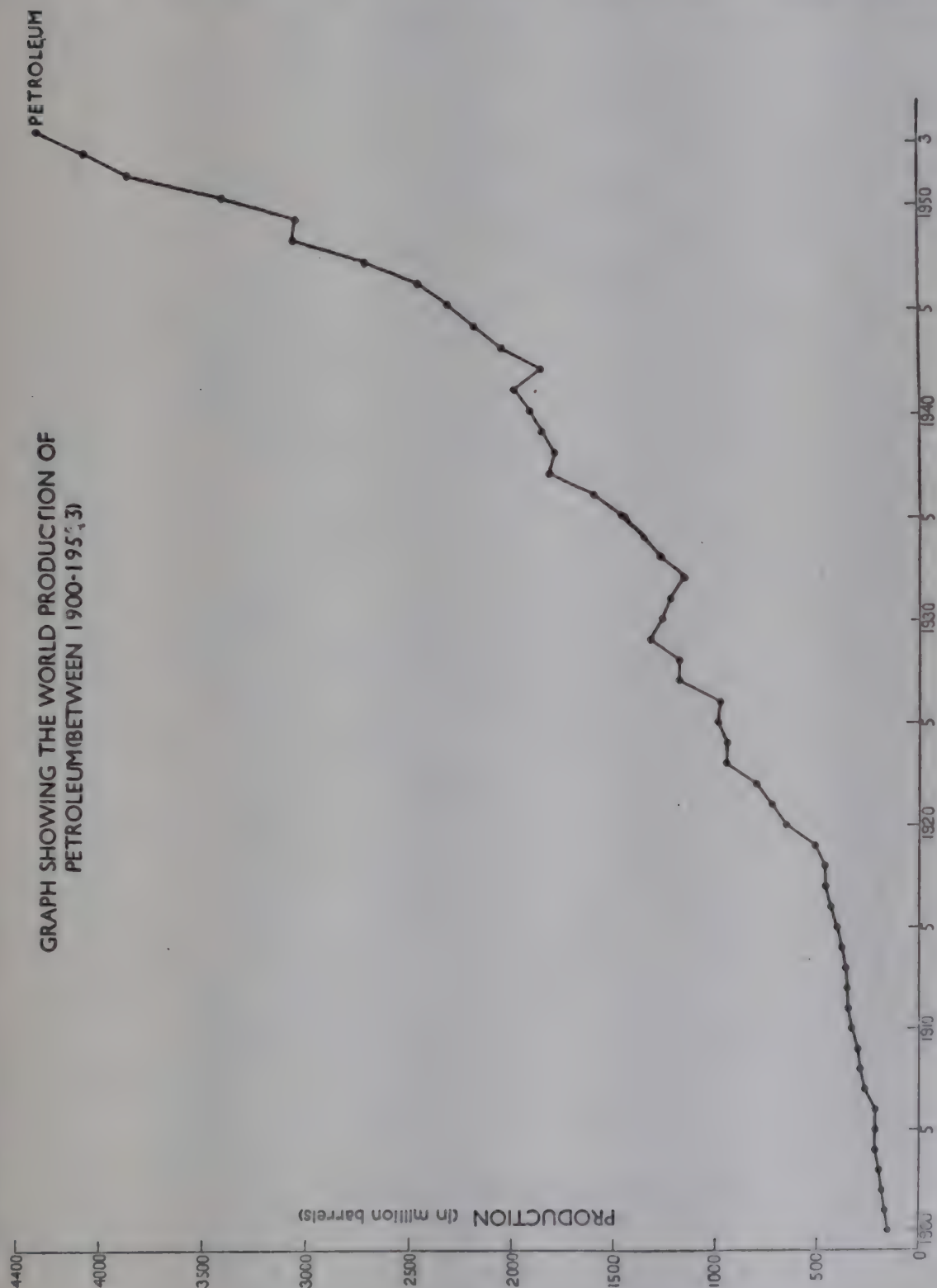
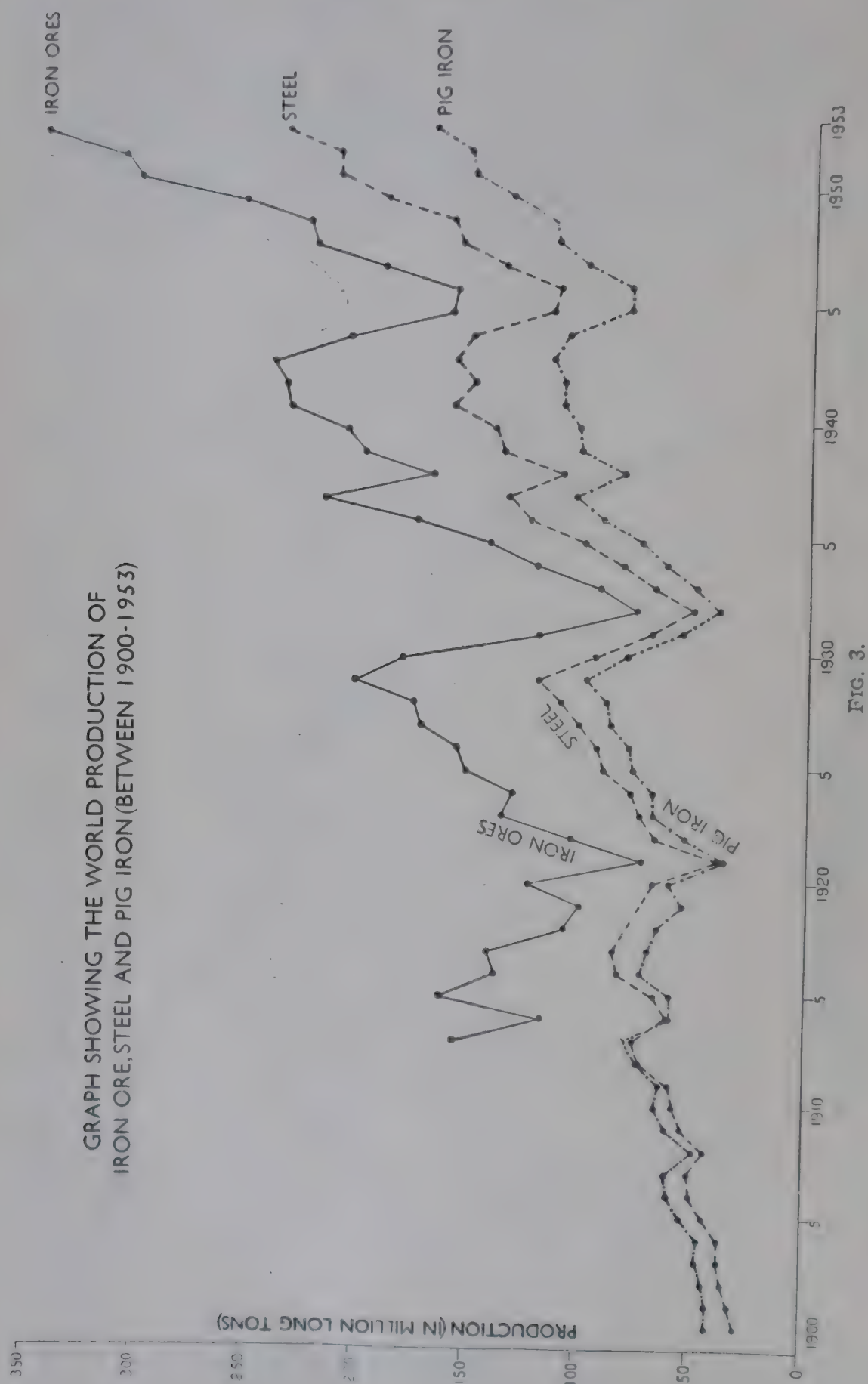


FIG. 2.



which originate from igneous rocks (especially metallic ores) are closely connected with mountain building activity, which, while creating new resources, may also destroy old ones. The last activity was the Alpine-Himalayan revolution, which geologically speaking, died down only very

GRAPH SHOWING THE WORLD PRODUCTION OF SILVER AND GOLD (BETWEEN 1900-1953)

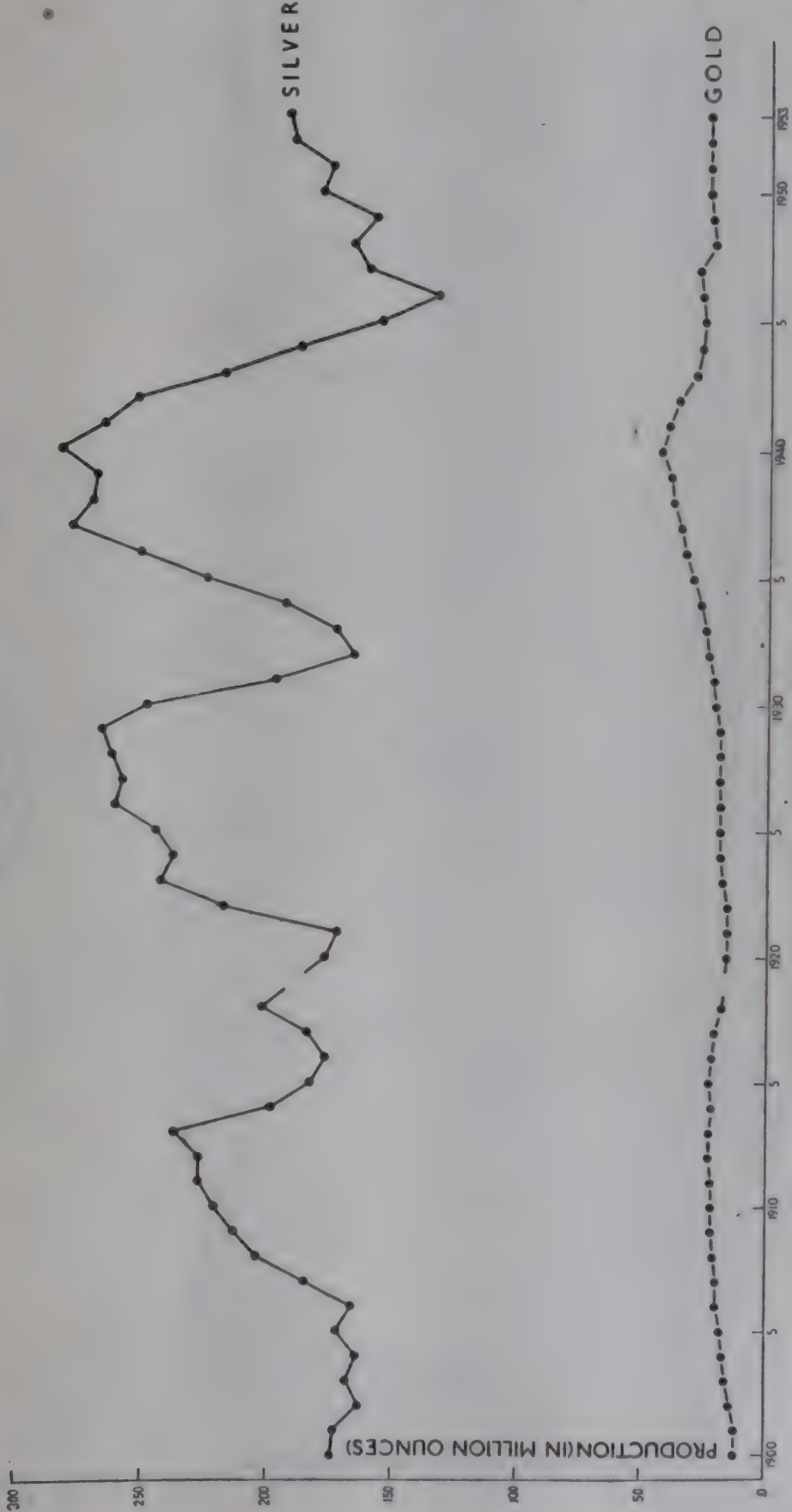


FIG. 4.

recently and the next one is not due, perhaps, for another 200 or 250 million years! The only way, therefore, of replacing the mineral deposits which have been depleted is to find new ones, wherever they may occur.

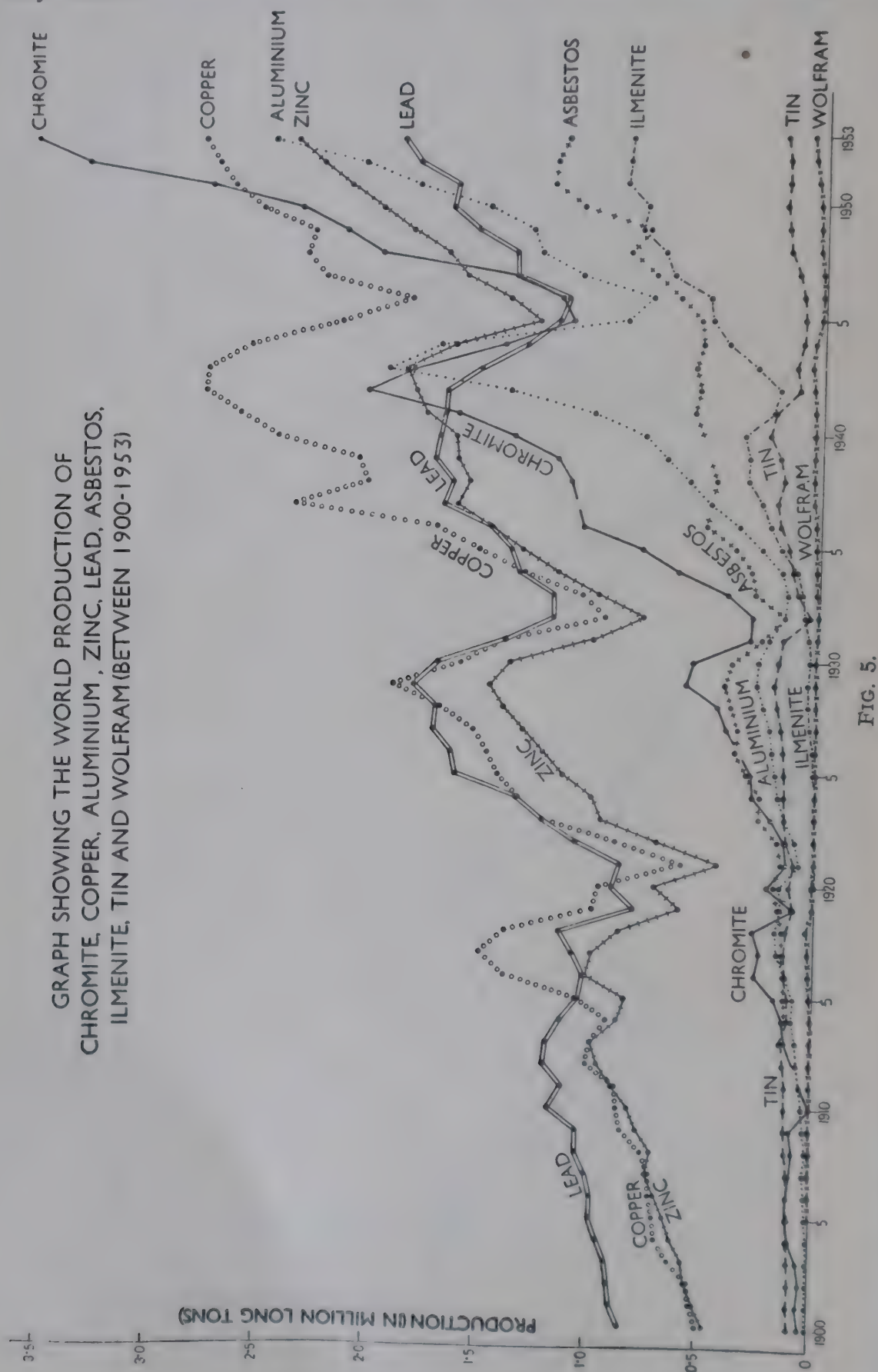
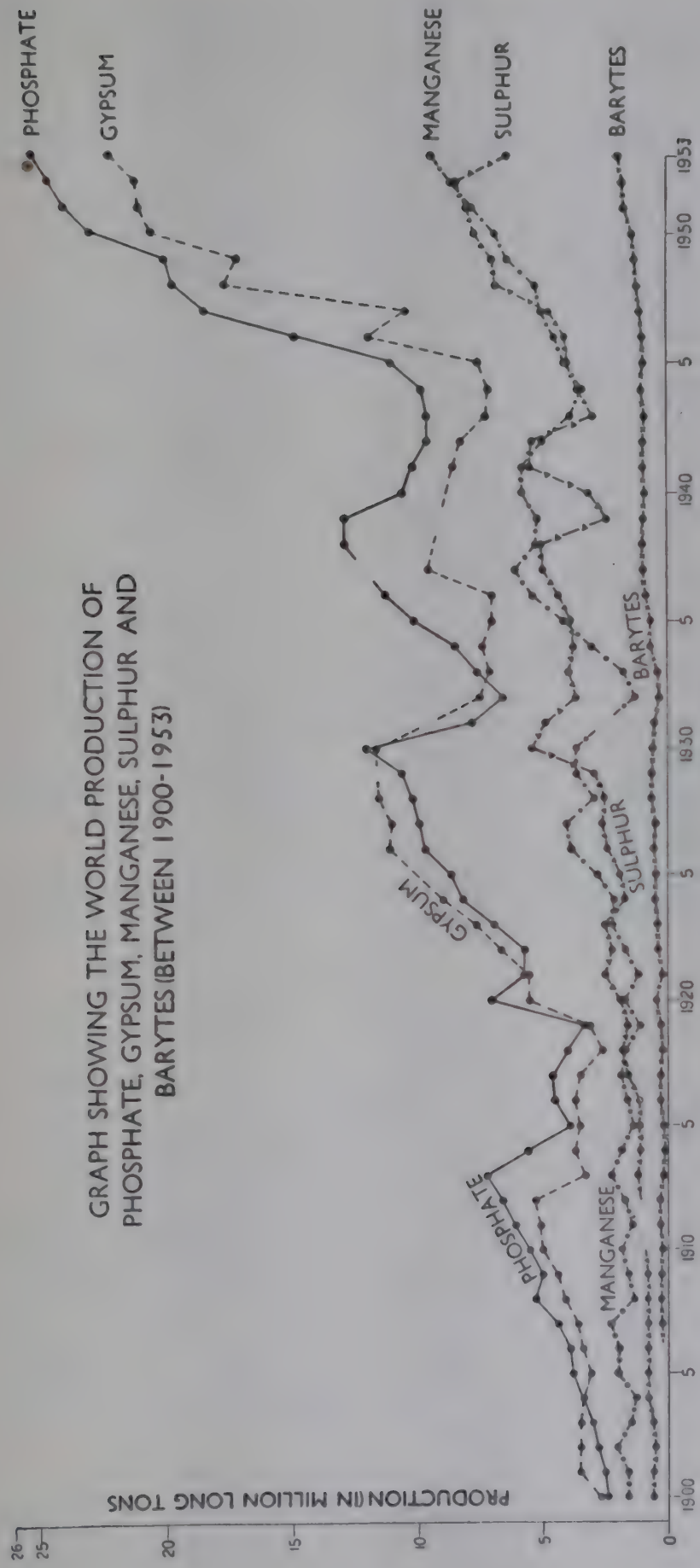


FIG. 5.



GRAPH SHOWING THE WORLD PRODUCTION OF
PHOSPHATE, GYPSUM, MANGANESE, SULPHUR AND
BARYTES (BETWEEN 1900-1953)

FIG. 6.

Minerals are classed as wasting assets. Some deposits originally thought to be of enormous size have been depleted so fast that they have now ceased production or lost their original importance. The Cornish tin mines which were the world's most important source for centuries are practically unproductive at present. The metalliferous mines near Freiberg in Germany (where there is a famous mining school) are not active at present. The copper deposits of Michigan, the silver mines of Potosi in Mexico and the once fabulously rich Comstock lode in Nevada have lost their importance. Many famous mining camps in U.S.A. and Mexico are merely the ghosts of what they were and will soon be forgotten. The most productive petroleum well so far known in the world, *viz.*, Cerro Azul 4, at Tampico, Mexico, after having produced some 60 million barrels of crude oil, suddenly began giving only salt water. It started as a gusher in February 1916 when the oil shot up from the borehole to a height of about 600 ft. above ground and was giving a daily production of over a quarter of a million barrels for some time.

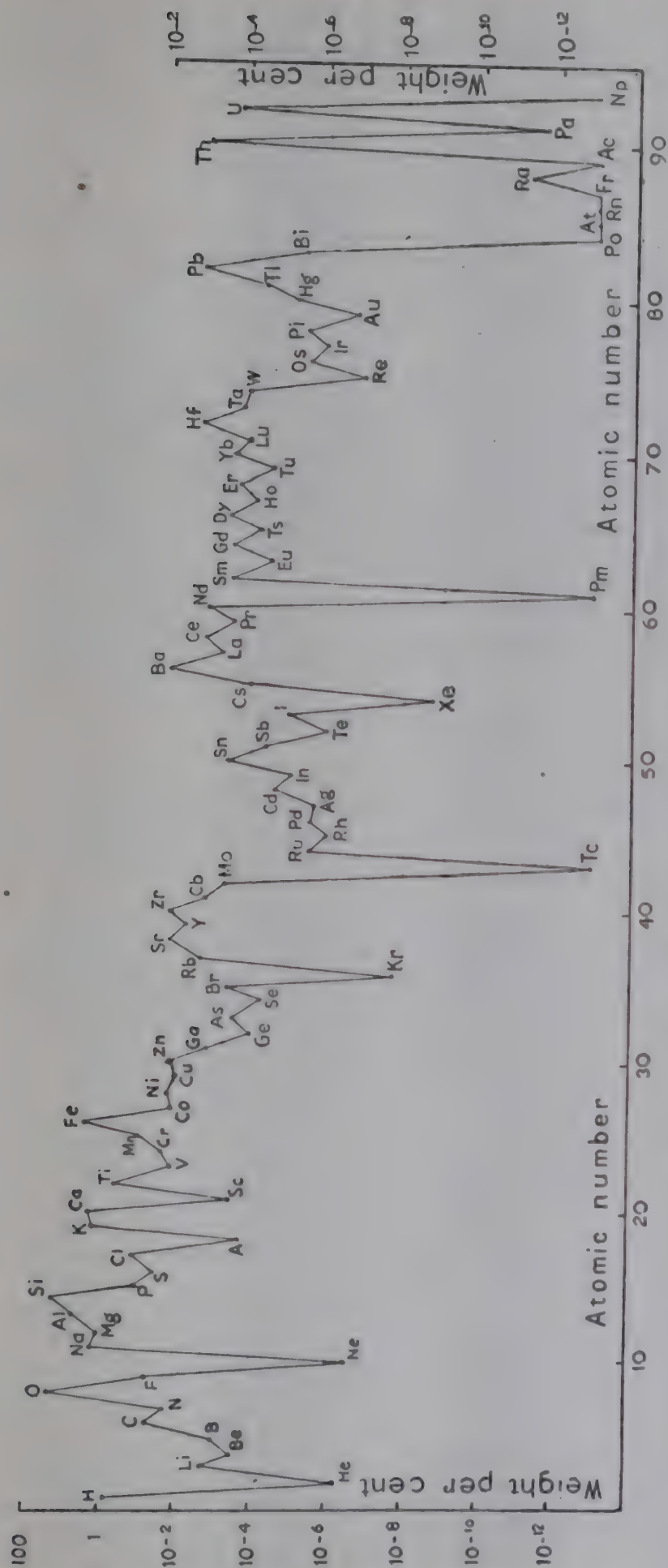
By far the great majority of deposits are very sporadic in distribution and rich deposits are distinctly rare. Coal and petroleum are more widely distributed, compared to metalliferous deposits. The coal bearing rocks of India occupy for instance 4 per cent or less of the area of the country, while the coal seams themselves occupy a small fraction of the coal measures. A large part (about 30%) of the production of copper by the U.S.A. comes from an area of barely 4 sq. miles near Butte, Montana. Over four-fifths of the world's nickel comes from the Sudbury mines in Canada and most of the world's production of molybdenum comes from a single property, the Climax mine in Colorado. The Rand gold deposits which are responsible for half the gold output of the world occur in an area 50 miles by 20 miles. Similarly the Kolar Gold Fields of India occupy an area of 5 miles by 1 mile.

We shall now turn our attention to the question of the abundance and distribution of the elements in the earth's crust and to problems of mineral development.

ABUNDANCE OF ELEMENTS IN THE EARTH'S CRUST

The earth has a radius of 6371 km of which about half consists of a core, presumably of the composition of an alloy of iron and nickel. There is an intermediate layer 2870 km thick which is thought to consist of silicates of magnesium, iron, chromium and also sulphides, tellurides and selenides. The crust is 30 km thick of which the ordinarily accessible portion comprises barely 3 km (10,000 ft.) though boreholes put down for petroleum have reached a depth of 20,000 feet. The composition of the crust is fairly well established through the work of such well known authorities as E. de Beaumont F. W. Clarke, H. S. Washington, V. M. Goldschmidt, J. H. L. Vogt, V. I. Vernadsky, A. E. Fersman and others. The average composition is that of a rock intermediate between granite and basalt, which are most prevalent igneous rock types exposed at the surface.

The abundance of elements forming the earth's crust is given in figure 7 (see also Appendix I). Taking only the top 10 km. of the crust, including the atmosphere and the oceans, the 12 most abundant elements are those given below in Table 1. They form 99.5 per cent by weight of the crust, all the other 86 elements together forming only one-half of one per cent.



ABUNDANCE OF ELEMENTS IN THE EARTH'S CRUST

FIG. 7.

TABLE 1
THE MAJOR ELEMENTS IN THE CRUST.

Wt. per cent				Wt. per cent			
Oxygen	...	...	49.5	Potassium	...	...	2.4
Silicon	...	...	25.7	Magnesium	...	...	1.9
Aluminium	...	...	7.5	Hydrogen	...	...	0.9
Iron	...	...	4.7	Titanium	...	...	0.6
Calcium	...	...	3.4	Chlorine	...	...	0.2
Sodium	...	...	2.6	Phosphorus	...	...	0.1

The most interesting fact about the composition of the earth's crust (and indeed of the whole earth) is that it is composed very largely of a few elements of comparatively low atomic number. Another fact is that elements having even atomic numbers are more abundant than their immediate neighbours with odd atomic numbers. A few exceptions there are, especially the rare gases Helium, Neon, Argon, Krypton and Xenon. This may be due to their having escaped from the earth at an earlier stage of its history ; that this supposition is plausible receives support from the cosmic abundance of these gases. Hydrogen and Helium are indeed by far the most abundant elements in the universe. In the case of some of the other elements, the reason may be that we have taken only the crust and not the whole earth, in the interior of which iron, nickel, magnesium and chromium (and possibly also sulphur, selenium and tellurium, etc.) are believed to be abundant. On the other hand, elements with the highest atomic numbers disintegrate spontaneously into those of lower numbers, at least under the conditions with which we are familiar on the surface of the earth and these elements should be expected to be amongst the least abundant. Elements with atomic number 43, 61, 85, 87, 93, 95, 96, 97 and 98 have so far not been reported as occurring in the rocks of the crust, either because they are very scarce or are very quickly transformed and removed.

Those who are not familiar with geochemical facts are apt to confuse our familiarity with the various elements with their abundance in the crust. Quite a few commonly known metals such as chromium, zinc, nickel, copper, tin, lead, antimony, mercury, silver, platinum and gold, and non-metallic elements fluorine, nitrogen, boron, bromine, iodine will be seen to occur only in minor amounts, though they are in common use. Some elements such as rubidium, gallium, germanium, hafnium, indium etc. though comparatively abundant amongst the minor ones, are so dispersed that they are not commonly known. Gallium accompanies aluminium, hafnium goes with zircon, while cadmium, indium and germanium are close associates of zinc. Some of the so-called 'rare earths' are more abundant than mercury, silver, gold and platinum. Scandium is more abundant than arsenic. Even titanium, which is one of the really abundant elements (about 0.44 per cent in the crust) is dispersed in ferromagnesium minerals to a great extent or occurs as small grains (as ilmenite and rutile) in many rocks, that important deposits of high grade are not common. The beach sands in some parts of the world containing ilmenite (Fe-Ti), Zircon (Zr), the monazite (Ce-Th-U) owe their concentration to weathering agents and to the action of rivers and sea waves. It would be quite uneconomic to dig up huge quantities of gneissic rocks in which these minerals occur sparsely distributed as minute grains, and try to concentrate them by mechanical means, though this is possible if cost is no consideration.

In contrast to the well defined, large and economically workable deposits of copper, lead, zinc, chromium, nickel, mercury, silver and gold,

many elements occur in a limited group of minerals which may sometimes form workable deposits. Such are the minerals containing lithium, beryllium, columbium, tantalum and rare earths which are found as sporadic lumps and pockets in pegmatites.

It will be clear from this that it is not the relative abundance of elements in the crust that matters so much as the degree of concentration and the quantity in which they are gathered up by natural processes. Such concentrates are our ore and mineral deposits. As our knowledge grows about the characters of the elements, the minerals formed by them, the processes which serve to segregate them into workable masses, the physico-chemical laws which govern their relationship and environment, we are able to narrow down our field of search and eliminate unfavourable environments.

The knowledge of the physico-chemical characters and of the processes of segregation of the elements enable us to understand the nature and association of minerals formed during the course of differentiation and fractionation of igneous rocks and those formed under sedimentary and metamorphic processes. The ionic potential (electric charge by ionic radius) determines, in sedimentary processes, the elements which remain in solution and are removed thereby and those which are precipitated by hydrolysis. A clear idea is thus gained of the process of clay and bauxite formation and the elements which may be expected to be present in such deposits. For instance, the red mud got in the Bayer process of alumina manufacture is now a good source of gallium.

GRADE AND WORKABILITY

Most of the ore deposits are usually derived through the agency of magmatic processes, being associated with igneous rocks and emanations. Both the grade of the ore and tonnage have a definite relation to what we consider a workable deposit. What we call a *low grade* is dependent on economic considerations of winning the useful mineral first by separating it from the unwanted minerals and waste rock, and then processing or smelting it to concentrate the mineral or metal into a usable form. We may state that at present the following percentages of metals form the lower limit of workable grade in deposits:

<i>Metal.</i>		<i>per cent.</i>
Aluminium	...	35
Iron	...	30
Manganese	...	25
Chromium	...	25
Zinc	...	5
Lead	...	4
Nickel	...	1.5
Copper	...	1.0
Tin	...	1.0
Silver	...	0.05
Gold	...	0.001
Platinum	...	0.001

These figures do not apply in all cases for the same element, for other factors such as the size of the deposit, its accessibility, the availability of suitable process for easy treatment, presence of other elements which may constitute valuable by-products, etc., enter into the problem of workability.

Thus an iron carbonate ore containing 30% iron may be workable but not a hematite of the same iron content. A bauxite containing 40% aluminium may be workable, but not a clay, as source of aluminium. Copper ores containing 1 per cent copper can be exploited if occurring in very large tonnages, as in the 'porphyry copper ores' of Western United States. Gold ores occurring as veins with 2 dwt. of gold to the ton are workable only under ideal conditions. In certain cases, because of specially favourable conditions or due to the availability of efficient processes of treatment, it may be possible to recover ores containing very low concentrations of metal. Gravel deposits containing about 3 grains of gold to the ton, and granite containing one-half or one-third of one per cent of tungsten ore may be worked. A very interesting example is sea water which contains only 0.13% of magnesium, which is now used as the source of that metal. The average content of uranium in rocks of the crust is of the order of 0.0002 per cent, *i.e.* two parts in a million. But it will be a very costly proposition to mine half a million tons of rock to process it and recover 1 ton of uranium whose market value at present is roughly Rs. 35,000 to Rs. 40,000. Barely a decade ago a workable uranium ore had to contain not less than 2 per cent of that element. But the demand that has been created after the discovery of atomic energy makes it now worthwhile to mine and process an ore containing only 0.1 per cent uranium. It will be a long time before it becomes possible to work even the granitic rocks which contain 5 to 10 parts of uranium per million parts, for their uranium content.

WORLD RESOURCES OF MINERALS

A large number of minerals, well over a hundred in number, are in use at present. A large proportion of them enter into the international trade as only a few countries are large sources of certain minerals and most others are dependent on these sources for their requirements.

In a paper presented before the United Nations Conference on Natural Resources in 1949 by the U.S. Geological Survey and the Bureau of Mines, the world resources, as known at the time are given for a few of the more important minerals and metals. Table 2, reproduced from that paper, indicates the reserves in millions of tons, the then production and the life of the reserves based upon current consumption.

The figures given in table 2 can only be an approximation to the truth and may, therefore, be taken as indicating the order of magnitude. In the case of iron and coal there are doubtless larger resources than shown in the above table. In fact, a study of the world resources of iron ores made in 1954 shows much higher figures than those given in the Table. For copper, lead and zinc it is rather interesting that the estimated life of the reserves has remained more or less stationery at 30-45 years over a period of more than two decades, the reason being that new reserves are being found to keep pace with the depletion.

In making any estimate of the life of the known reserves at any time, various assumptions have necessarily to be made. One of these is the current rate of consumption which naturally varies from country to country and from region to region. Table 3 gives an idea of the *per capita* consumption of the most important metals, coal and petroleum in the U.S.A., in Europe excluding U.S.S.R., and in the rest of the world. A glance at the table will show a great disparity in the rate of consumption which of course depends on the status of industrial advancement of the different regions. If the rate of consumption increases in the under-developed countries the life of the reserves will naturally be reduced.

TABLE 2
WORLD RESERVES AND CONSUMPTION OF SOME MINERALS

	World Reserves	Production 1947-48	Supply at present consumption (years)
	(in million tons)		
Iron ore (Iron content)			
Actual 	19,000	91	200
Potential 	57,000		
Manganese (50% equivalent) ...	1,000	3.9	350
Chromite 	100	2.1	47
Wolfram (60%) 	4	0.032	125
Copper ore (metal content) ...	100	2.2	45
Lead ore " ...	40	1.2	33
Zinc ore " ...	70	1.8	39
Tin ore " ...	6	0.16	38
Bauxite 	1,400	6.5	200
Potash 	5,000	3	1600
Phosphate rock 	26,000	14.4	1800
Coal & lignite (coal equivalent) ...	5,165,000	1,500	2200*
Petroleum			
(Proved & indicated)	75,000†	3,400†	22
Ultimate 	555,000†	—	—

* Allowing for one third loss in mining.

† Million Barrels (roughly 7 barrels to a ton).

TABLE 3
PER CAPITA CONSUMPTION OF SOME METALS AND MINERALS
(as in the year 1948)

	U.S.A.	Europe ex. U.S.S.R.	Rest of world	World average	India
Iron (kg)	335.0	65.0	11.0	39.0	6.0
Copper (kg)	8.2	1.8	0.2	0.9	0.1
Lead (kg)	4.7	1.3	0.1	0.6	0.02
Zinc (kg)	4.9	1.5	0.1	0.7	0.1
Tin (kg)	0.42	0.14	0.01	0.06	0.01
Coal (met. ton)	4.3	1.3	0.2	0.6	0.1
Petroleum (bbls)	13.8	0.8	0.4	1.3	0.1

OUTLOOK FOR DISCOVERIES.

As is well known, only a few limited areas in the world have been searched intensively for minerals. Such areas are to be found around the North Atlantic, *viz.*, in Western Europe and North America. Even there the amount of detailed exploration that has been done varies greatly from one area to another. Parts of the Canadian 'shield' for instance, are yet to be examined in detail. Similarly, there are parts of the Rocky Mountain belt which have not yet been investigated properly.

In other parts of the world it may be stated that only a few small areas have been examined in detail. The greater part of South America, Africa and Asia remain to be explored with care. In Asia and Africa there are regions which have not yet been mapped geologically. Under

the circumstances, it is reasonable to expect that intensive exploration and prospecting in such areas in these continents would lead to the discovery of a number of mineral deposits of which some at least would be of importance.

INVESTIGATION TECHNIQUES

Discovery will, of course, depend upon the care, perseverance and skill employed and the efficacy of the methods used. The days of the common prospector are more or less over in many countries where good geological surveys exist. Only in the more inaccessible parts of these countries would surface examination now give worthwhile returns. The geological surveys of most countries are now engaged upon the systematic examination of their territories with the help of geophysical, geo-chemical, radio-active and other methods of prospecting aided by drilling and microscopic examination, chemical analysis, etc. of the minerals obtained during investigation. In areas covered by soil, geo-chemical techniques are very helpful to trace the distribution of certain elements which are sought after or which lead to the discovery of certain other elements with which they are associated. A careful study of the structural aspects of mineral deposits is proving highly useful as it gives a better knowledge of the behaviour of the deposits both laterally and at depth. The methods available to the geologist are constantly being improved upon by advances made in the fundamental sciences which contribute to the development of new types of equipment and new methods of work. Geophysical prospecting has, in the last three decades or so, given spectacular results, particularly in prospecting for oil where it has been used most extensively. Recent developments pertain to the use of the magnetometer from the air, *i.e.*, aeromagnetic prospecting, which is specially useful in unexplored or poorly explored areas. Even in countries where a considerable amount of prospecting has already been done, new discoveries are being made at depth. For instance, the concealed coalfields in Southern England were discovered by careful geological work aided by deep drilling which proved the existence of several valuable coal seams at depths of 4,000 to 5,000 ft. from the surface. It is obvious that the use of the modern methods of prospecting in all parts of the world would lead to the discovery of what lies at depth.

PROSPECTING FOR PETROLEUM

Formerly an appreciable part of the discovery of oil-fields was due to the results obtained from wild-cat drilling. In fact several successful wild-cat wells were drilled against the geological advice available at the time. In any case, whether the drill holes were successful or not, they furnished much valuable geological information. As a result of exploration for several decades it is now known that petroleum is found in sedimentary rocks mainly of marine origin. What sort of organisms gave rise to petroleum and what particular processes control its characteristics are still matters of controversy. When these sediments are moderately folded, forming domes and anticlines, they provide the necessary structure for the accumulation and storage of petroleum. The 'reservoir' rocks must be porous in order to be able to hold large quantities of petroleum and gas, and pervious in order to yield them readily when pumping is resorted to. The porous strata should have an impervious cover to seal off and to prevent the escape of the petroleum and the accompanying natural gas from the adjoining strata. The strata must be unbroken by faults and

thrusts, for these afford easy routes for the escape of petroleum and gas. Thus, though the Siwalik and the associated Sub-Himalayan zone bordering on the North Indian plains belongs to the same sedimentary belt as occurs on either side of India in Iran and Burma, it has been violently elevated, broken up, folded and pushed about by the earth movements which were responsible for the formation of the Himalayan ranges. We have, as a result, the highest mountain ranges in the world, attracting many mountaineering expeditions from all parts of the globe ; but unfortunately, from the economic point of view, the very forces which produced these mountains have broken up most, if not all, of the possible oil bearing structures. We still entertain some hope that a few favourable structures may be found in this belt as well as in the Ganga and Brahmaputra valleys of Northern India under the thick blanket of alluvium.

The discovery of the great majority of the oilfields during the last three decades or so is due almost entirely to geophysical exploration. Many parts of the world have been investigated, resulting in numerous discoveries such as the fields in Central Canada, England, Germany and Saudi Arabia. Similarly also, the Nahorkatiya field in Assam owes its discovery entirely to geophysical prospecting. Without these aids, the discovery would have been much slower and only through expensive blind drilling at very great cost.

GEOLOGICAL ENVIRONMENT

The search for minerals has another aspect. By patient accumulation of data, general principles have been established which enable us to say that certain types of minerals are found in specific geological environments. With that knowledge we can say that it is futile to look for coal or petroleum in crystalline rocks or even in Pre-Cambrian sedimentary rocks. Indeed, there is a record of one of our Provincial Governments, nearly three quarters of a century ago, repeatedly helping an enthusiastic army officer in his search for coal in the crystalline and Pre-Cambrian rocks, against the advice of the Geological Survey. Certain minerals like chromite, vanadiferous and titaniferous magnetite, nickel sulphide, phlogopite, chrysotile asbestos, the platinum group of metals, etc. are found in igneous rocks rich in magnesium and poor in silica which geologists call ultra-basic rocks. The granite-pegmatites are the home of several minerals containing rubidium, caesium, lithium, beryllium, cerium, yttrium, tantalum, etc. Tin and wolfram are also found in granitic rocks. Many of the metalliferous deposits containing ores of copper, lead and zinc are generally associated with igneous rocks of acid to intermediate composition (granites or grano-diorites).

A very rough quantitative appraisal of different types of minerals available in the chief geological formations exposed in a country may be made if reliable fundamental geological data are available. These latter should of course include the structure, thickness and distribution of the various geological formations and the type of mineralisation associated with them. To arrive at a general picture it is not necessary that the appraisal should be accurate in the first instance. The order of magnitude may be first ascertained in the preliminary studies, further search and closer investigation aiding in making this more and more precise in course of time.

GRADE AND TONNAGE

In most mineral deposits, there is some quantitative relationship between the grade of the mineral and the tonnage available, *i.e.* the poorer

grades are in greater abundance than the rich ones. The relative proportions of the tonnage of the different grades will depend upon the geological characteristics of the deposits. The ratio of these grades may vary from one group of deposits to another. This type of study has not been undertaken yet on a systematic basis, but as data become available from areas where the mining industry has been in existence for many years, it should be possible to establish, for each type of deposit, some kind of mathematical relationship which would aid future appraisal.

The present surface of the globe gives a section of the earth as exposed by geological processes. Below the present surface and within the depths accessible to mining, we can expect at various levels a general repetition of the same conditions and the same average distribution of rocks and mineral deposits. This assumption will be valid if we take the earth's surface as a whole. Broadly, therefore, we shall be justified in assuming that there are at least as many undiscovered deposits below ground as those that have been discovered and exploited. Indeed, if we could explore all the mineral deposits occurring down to a depth of, say, 10,000 ft. from the surface, we should certainly expect to find several times the reserves of all the minerals which we are cognizant of at the present time. As things are, however, there is a great deal of exploration to do and there is no doubt that numerous important deposits await discovery in many parts of the world.

CONSERVATION OF MINERAL RESOURCES

It is well-known that in all countries there is a stage of development early in the process of industrialisation when only the richest deposits exposed at the surface are worked and utilised locally or exported. Much wastage occurs in this stage either through leaving behind the poor grade material unworked or throwing it away with waste rock on the dumps. This stage is soon followed by industrial development marked by the setting up of metallurgical, chemical and engineering works. The national wealth and prosperity of the country concerned increase during this stage. Next comes a period of depletion of cheap domestic mineral resources and import of raw materials from outside for feeding the local industries. During this stage the general prosperity of the country is maintained but there is keen competition in markets both for buying raw materials and selling finished goods. Thereafter comes the stage of having to depend on foreign ore and other raw materials, leading gradually to loss of competitive power in foreign markets due to the necessity for purchase of much of the raw material requirements from outside. We in India are just passing the first stage and entering into the second. The further stages can be strengthened by the careful husbanding of our resources by the adoption of measures of conservation. This can be achieved if an all-out effort is made to adopt and enforce the best practices in mining ; to insist that all workable grades are mined and that the poorer grades are beneficiated in order to make them usable ; that all useful byproducts are recovered during mining, beneficiation and manufacture ; and that each type or grade of material is put to the use to which it is best fitted by its properties. An outstanding example in India requiring the enforcement of conservation, to which repeated attention had been called, is the misuse of good coking coal for burning in boilers and locomotives for steam raising for which non-coking coal of a similar grade would do quite well. It is only during the last four or five years that serious steps have been taken to prevent the objectionable use of coking coal. Several other examples of waste or misuse can be quoted.

It is, however, necessary to develop a sense of proportion and weigh the local conditions carefully before strict measures are adopted to prevent waste. We are apt to complain that the excellent marbles of Makrana in Jodhpur and other places in Rajasthan are being used for building huts in the neighbouring villages, or that the beautiful shell limestone in the Trichinopoly district in Madras is carved into water troughs for cattle. In the absence of better uses, or rather of any organisation for encouraging the marketing of the materials for better uses, it is inevitable that they are employed locally for purposes for which some other and cheaper material could have been used.

During periods of high prices and scarcity, miners themselves adopt some measure of conservation by working the readily marketable lower grades of mineral present in the mines or by re-working the dumps to recover whatever can be sold in the market. Thus, during the last few years, under the stimulus of high prices, many manganese mine dumps were scenes of activity and appreciable quantities of marketable ore were recovered. During the war, many mica dumps were turned over to recover small pieces of good mica and such minerals as beryl, tantalite, samarskite, etc. This, however, is a process depending on special circumstances when either high prices or scarcity encourage the recovery of all useful material even from dumps. The modern State, whatever be its political complexion, now insists that natural resources should be conserved and takes steps to regulate the mining and mineral industries to the extent considered necessary in the interests of the nation. It encourages and helps the industry to set up plants for beneficiation and undertakes research to determine the most suitable processes to adopt for the particular mineral commodities selected for beneficiation. As private industry becomes more educated and alive to the need for conservation, it may itself take up research to solve the problem of individual units or of the particular mineral industry as a whole.

Conservation has to be effected at all stages of the development of the mineral deposits, in mining, milling and ultimate utilisation. All technological advances in any of these stages automatically bring in improvements which are conducive to conservation. Conservation is also achieved by substituting a more easily available and cheaper material for one which is costly or difficult to get. Substitution is often dictated by necessity and will be acceptable so long as the easily available substitute is good enough for the purpose for which it is intended. Thus, though it may be worth while using a good grade of mica for all types of electrical insulation, a poorer insulator would serve for some purposes. Mica substitutes are, therefore, coming into use in the countries which have to import this mineral in large quantities.

RECOVERY OF BY-PRODUCTS

Barely a quarter of a century ago, many minor metals or elements present in important mineral deposits, such as those of copper, lead and zinc, were considered to constitute an unmitigated nuisance. Such were arsenic, antimony, cadmium, bismuth, molybdenum, tungsten, vanadium, etc. which are found in small quantities in metalliferous deposits and whose elimination costs a good deal of money. But, at the present day, the presence of such elements constitutes a valuable source of profit as they are separated, refined and sold in the market. Even coal ash, slag and flue gases and dust from chimneys have become important sources of sulphur, potash, germanium, etc.

About half a century ago, the only petroleum fraction which found use was the heavy fuel oil. The crude petroleum drawn from wells was run out into open pits or tanks so that the light fractions might escape, leaving the heavy oil behind, for no use had been found for the lighter constituents. Now-a-days these light fractions, which were considered useless in former days, are the most valuable constituents and every effort is made to prevent their loss.

Technological advances are constantly enabling us to use lower grades of minerals than before. Within a period of two decades or so, the ore charge for the iron blast furnace in America has gone down from an average of 56 to 60 per cent iron to 52 to 55 per cent iron. The standard grade for bauxite which was formerly over 55 per cent alumina has now dropped to below 50 per cent. Chromite and manganese ores of 45 and 40 per cent respectively are now-a-days saleable but a couple of decades ago, they had no market. When certain materials become scarce in time of crisis the prices shoot up to unprecedented heights—*e.g.*, wolfram was selling at a price of Rs. 25,000 or more per ton barely 3 or 4 years ago, while beryl was selling at more than Rs. 1,000 per ton. But if the scarcity becomes chronic, substitutes will be found by intensive research and the scarce mineral will not be needed for the purpose for which it was originally used. These remarks will apply as much to artificial scarcity which may be created by political or ideological factors as to natural scarcity due to insufficiency of reserves or supply.

CHANGING PATTERN OF USE

It is an interesting fact that no mineral has become entirely obsolete and unusable. The pattern of use may change occasionally, but so long as a mineral finds some use it continues to be employed until it is replaced by something more suitable or is used for some other special purpose. A good example is afforded by monazite for which the black sands of the Travancore coast were originally worked. It was then employed for the requirements of the gas mantle industry. But, after the first World War, the demand for the mineral fell and practically stopped, as gas had largely been replaced by electricity for lighting in Europe. In the meanwhile, ilmenite which is associated with the monazite, found use in the manufacture of a paint pigment—*titanium white*. This mineral rapidly assumed importance and monazite was nearly forgotten for a while. But during and after the second World War, monazite has again attained prominence as a possible source of atomic energy because of its content of appreciable amounts of thorium and a little uranium. Ilmenite also continues to be utilised, so that at present there is a good demand for both these minerals.

Prophets are not wanting to predict calamities for particular mineral industries whenever important new developments take place. Some have predicted that, because of the coming in of synthetic mica and *samica*, the natural mica which India produces in large quantities will shortly disappear from the list of useful minerals. But I am sure that most geologists will agree with me that so long as good natural mica is available at a competitive price compared to any synthetic product or substitute, there will always be a market for it. It might go out of use only if something equally efficient and not costlier takes its place. The latest prophecy seems to be that atomic energy is going to make coal an unwanted material and that coal mining will be a thing of the past within a decade. But we may well ask whether all the uranium needed

for bringing about such a complete revolution in the industrial set-up and power production will be available (as also other materials needed for regulation and control of the nuclear reactions) at a price which will compete seriously with coal. Similar prophecies were made about coal when large developments in the production of petroleum as well as of hydro-electricity took place three or four decades ago. There are as yet no signs of coal becoming unnecessary to mine.

Conservation of natural resources is the slogan of the present age, so much so that a World Conference on this subject was held under the auspices of the United Nations in New York in 1949. Those interested in the subject will find much useful information in the six volumes of the report of this Conference published in 1953 by the United Nations Organisation.

INTERNATIONAL CHARACTER OF MINERAL RESOURCES

Modern industry uses a host of minerals. Some of these used to be called *strategic* in the sense that they were of importance for making the munitions of war. Amongst these would come, for instance, ores of iron, manganese, chromium, tungsten, copper, lead, sulphur, etc. But in this era of total war, almost everything becomes a strategic material—even ceramic clay and paint pigments—for each has an important part to play. Hence the necessity for finding and developing all the variety of minerals needed for various industries.

Several important studies have been made in recent years by individuals and committees to assess the resources of minerals available in each country as also the local needs and exportable surpluses. But now, in many cases, the demand is outstripping supplies from well known sources so that what appeared to be adequate reserves a few years ago are no longer so. Only some overwhelmingly important deposits have continued to be the major suppliers, while all the small or moderate sized deposits have been depleted or even used up. There is thus a concentration of supply in the territories of a few individual countries. Not even the biggest countries in the world like the Soviet Union or the U.S.A. are self sufficient in all minerals and they have to obtain a few minerals from other countries. Minerals, therefore, assume international importance and figure prominently in political and economic discussions between countries. No wonder then that all countries are paying increasing attention to the development of their mineral resources to reduce their dependence on others to a minimum.

Some 70 to 80 minerals are known to enter into inter-national trade. In the case of a few like tin, tungsten, chrome, nickel, etc., the sources are few from which supplies must be obtained by all. In the case of some others the sources are many and therefore it is more easy to obtain them from several alternative suppliers. The growing industrialisation of several countries has been creating shortages because of which supplies are rapidly becoming limited to only a few sources which have a large surplus for export. In regard to the chief sources of supply of the more important minerals, I take the liberty of quoting an extract from a lecture delivered at the Hyderabad Session of the Indian Science Congress by Prof. Alan Bateman of Yale University:

“As I foresee it, the chief supplies of minerals of the free world in the future will be as follows:

Mexico for lead and zinc, antimony, mercury and graphite; Venezuela for petroleum and iron ore; Brazil for manganese, iron ore, beryl,

tantalum and mica ; Bolivia, tin, tungsten and antimony ; Chile, copper and nitrates ; Peru, Copper, lead, zinc and vanadium ; Canada, copper, lead, zinc, asbestos and nickel ; Morocco, lead, zinc, manganese, cobalt, iron ore ; Algeria and Tunisia, lead and zinc ; South Africa, manganese, chrome, asbestos, diamonds and corundum, as well as uranium ; Namaqualand and South West Africa will supply copper, lead, zinc, tungsten and germanium ; the Rhodesias will supply copper, cobalt and some lead and zinc along with important quantities of metallurgical chrome and asbestos ; the Belgian Congo can supply copper, cobalt, uranium, lead, zinc, tin, tantalum and diamonds ; British East Africa in the future will be able to supply copper, cobalt, iron ore, possibly manganese and mica ; Portuguese East and West Africa can supply diamonds, some mica, some tungsten, possibly in the future some uranium ; the West Coast of Africa has large reserves of iron ore and manganese, diamonds, and miscellaneous minerals ; Turkey will have exportable surpluses of metallurgical chrome ; the Philippines can supply iron ore and refractory chrome ; Korea can supply tungsten ; Japan can supply little of anything for mineral export ; Indonesia in turn will have excesses of bauxite, petroleum and tin ; Malaya, of course, should continue to be the largest exporter of tin ; and India, it is expected, should have exportable surpluses of manganese, of mica and titanium ore ; New Caledonia should continue to yield nickel and chrome ; and Cuba in the future should be a large supplier of nickel as well as considerable manganese and refractory chrome."

Times of emergency create abnormal demands for minerals. Familiar sources of supply beyond the confines of a country may be cut off, necessitating the opening up of poor deposits at home and taking resort to substitutes which may not always be very satisfactory. Frantic search is made and all new sources—good, bad and indifferent—are tapped at great cost, most of them to be abandoned at a later date as uneconomic. As examples we may cite the development of poor grades of manganese ore and bauxite in the U.S.A., aluminous clay in Japan. A similar situation arose during the war in all the other industrially advanced countries and compelled them to pay concentrated attention to problems of mineral sufficiency and deficits. But in some cases, however, intensive research has enabled the utilisation of deposits considered marginal or unworkable in former days.

INDIA'S RESOURCES

During the last War, India was an important link in the supply chain of the British Commonwealth and had to face many difficulties due partly to lack of trained personnel and facilities and partly to lack of knowledge of the resources. With the subsequent change in Government has come the realisation of the urgent need to assess the country's resources in minerals and to use them in new industries to meet her own needs. Our present knowledge goes to show that we have only a few surpluses and quite considerable deficiencies in the list of useful minerals needed for industry. There is a sufficiency or surplus in coal, ores of iron, manganese, aluminium, titanium, chromium, magnesium ; mica, barytes, kyanite, sillimanite and various types of clays. The chief deficiencies are in copper, lead, zinc, silver, nickel, cobalt, molybdenum, tungsten, tin, antimony and mercury amongst the metals ; and sulphur, phosphates, fluor-spar, petroleum, potash, graphite, asbestos, amongst the non-metallic minerals. In almost every case our knowledge is confined to surface

observations. We do not know enough about what lies below the surface even at shallow depths. There is, consequently, a chance of making good, some of the deficiencies by extensive and intensive search in suitable areas. Only during the last few years has the Geological Survey been strengthened suitably in personnel and equipment to face this task adequately. Geological data can be gathered only by hard, painstaking work in difficult and often inhospitable terrain and at considerable expenditure of labour, time and money. Many who are unfamiliar with the nature of geological work believe that because the Geological Survey has been expanded, new discoveries will come pouring in by the dozen. Such hopes are unwarranted, but we can expect to get more precise information on the known resources and perhaps also make a few important discoveries. We must be prepared to face disappointments in some cases at least, where the yield of results may be quite disproportionate to the time, energy and money spent. This applies particularly to the search for petroleum in which the risks are much greater than in the case of most other minerals. Even in areas known to contain petroleum, it is only one deep drill hole in about 15 to 20 becomes productive. It is known that the Assam Oil Company has been conducting intensive geological and geophysical work and drilling in many areas in Assam during the last two decades or more, with practically negative results, until the new field of Nahorkatiya gave indications of success barely two years ago. Drilling is being continued there and the full potentialities of the field are not yet known. In entirely new areas such as we are beginning to explore, the chances of success may not be any better. I say this not to discourage efforts in any way, but only as a warning against pitching our expectations too high.

I have already alluded to the changing pattern of use of minerals to meet the ever-increasing demands by diversified industries. As science and technology advance, new tools become available for the search of minerals and new uses for minerals emerge. It is therefore quite impossible to make a claim that we know everything about all our resources at any point of time. As new demands arise, there will be need for re-examination of even well investigated areas and to search for whatever material or information may be required at the time. Hence a Geological Survey does not become superfluous at any time, for it can never have completed its job to finality. Only in 1931 a committee of the Central Government thought that there was not enough work for the Geological Survey, whose total strength at the time was some 30 geological officers for the whole of the "Indian Empire", and decided to prune it to about two thirds its size. The war which came soon after found us with this small personnel and great efforts had to be made to expand the Survey. Even though the Department is at present ten times its size in 1935, it is still inadequate to meet even the major part of the work it is expected to do, and further expansion is necessary. In addition, a Bureau of Mines has been established to look after the work of improving the techniques and standard of mining and of enforcing mineral conservation measures. An Oil & Natural Gas Division is being set up to undertake systematic and intensive exploration for petroleum. Within the Geological Survey itself there are specialist wings to study Mineral Deposits, Groundwater and Engineering Geology and to conduct Geophysical Exploration. The coordinated efforts of all these will be directed towards the study of all the phases of exploration and development of our resources in minerals and will contribute steadily to the building up of a strong and prosperous nation.

APPENDIX—I

COMPOSITION OF THE EARTH'S CRUST

(Grams per metric ton or parts per million).

	Each		Each
Oxygen ...	466,000	Beryllium ...	7
Silicon ...	277,000	Samarium ...	6·5
Aluminium ...	81,300	Gadolinium ...	6·4
Iron ...	50,000	Praseodymium ...	5·5
Calcium ...	36,300	Scandium ...	5
Sodium ...	28,300	Arsenic ...	5
Potassium ...	25,900	Hafnium ...	4·5
Magnesium ...	20,900	Dysprosium ...	4·5
Titanium ...	4,400	Uranium ...	4
Hydrogen ...	1,400	Boron ...	3
Phosphorus ...	1,180	Ytterbium ...	2·7
Manganese ...	1,000	Erbium ...	2·5
Sulphur ...	520	Tantalum ...	2·1
Carbon ...	320	Bromine ...	1·6
Chlorine ...	314	Holmium ...	1·2
Rubidium ...	310	Europium ...	1·1
Fluorine ...	300	Antimony ...	1·0
Strontium ...	300	Terbium ...	0·9
Barium ...	250	Lutetium ...	0·8
Zirconium ...	220	Thallium ...	0·6
Chromium ...	200	Mercury ...	0·5
Vanadium ...	150	Iodine ...	0·3
Zinc ...	132	Bismuth ...	0·2
Nickel ...	80	Thulium ...	0·2
Copper ...	70	Cadmium ...	0·15
Wolfram ...	69	Silver ...	0·1
Lithium ...	65	Indium ...	0·1
Nitrogen ...	46	Selenium ...	0·09
Cerium ...	46	Argon ...	0·04
Tin ...	40	Palladium ...	0·01
Yttrium ...	28	Platinum ...	0·005
Neodymium ...	24	Gold ...	0·005
Niobium ...	24	Helium ...	0·003
Cobalt ...	23	Tellurium ...	0·002
Lanthanum ...	18	Rhodium ...	0·001
Lead ...	16	Rhenium ...	0·001
Gallium ...	15	Iridium ...	0·001
Molybdenum ...	15	Osmium ...	0·001
Thorium ...	12	Ruthenium ...	0·001
Cesium ...	7	Others : below ...	0·001
Germanium ...	7		

SECTION OF MATHEMATICS

President : R. N. SEN, M.A., PH.D., F.N.I.

Presidential Address

PARALLELISM IN DIFFERENTIAL GEOMETRY

1. INTRODUCTION

I thank last year's Sectional Committee most sincerely for electing me President for this year. I greatly value the honour thus bestowed on me. I have chosen as the theme of my address a subject in which I have been interested for a long time, namely, parallelism in differential geometry, and I have attempted to give a brief account of the main results obtained in the sphere of parallelism from the beginning up to the present stage.

Since the discovery of General Relativity in 1916, the study of intrinsic differential geometry received a stimulus and many important and interesting discoveries were made in the field of generalised spaces and their differential invariants. Most important among them and the most fruitful for later developments was the concept of infinitesimal parallel displacement formulated by Levi-Civita in 1917. Whatever be the nature of the space, subject to satisfying the usual analytical conditions, with which one may be concerned, it is always necessary that the geometrical properties of our study should remain invariant when the coordinates x^i of the space are subjected to non-singular transformations

$$x'^i = f^i(x), \quad \left| \frac{\partial f^i}{\partial x^j} \right| \neq 0. \quad (1.1)$$

The study of the invariants of these transformations resulted in what is now known as the 'tensor calculus' which was discovered by Ricci as early as 1887. In general we have to deal with three classes of invariants, viz., the scalars, the tensors and the coefficients of affine connection which are defined by the manner in which they are transformed by (1.1). The last named invariant is a set of 3-index functions Γ_{jk}^i of the coordinates which are transformed as

$$\Gamma_{jk}^{'i} = \Gamma_{qr}^n \frac{\partial x'^i}{\partial x^p} \frac{\partial x^q}{\partial x'^j} \frac{\partial x^r}{\partial x'^k} - \frac{\partial^2 x'^i}{\partial x^q \partial x^r} \frac{\partial x^q}{\partial x'^j} \frac{\partial x^r}{\partial x'^k} \quad (1.2)$$

In the case of a tensor, which may have one or more indices, the law of transformation does not contain the second term on the right hand side of (1.2) involving the second derivative, while the scalar is an absolute invariant. In what follows a space will be supposed to be of n dimensions unless otherwise stated and the usual convention regarding summation as adopted in tensor calculus will be followed.

2. PARALLELISM IN AFFINE AND METRIC SPACES

According to Klein's Erlanger Programm (1872), affine geometry is the geometry of properties which remain invariant under the group of affine transformations. Now when the coordinates are transformed by (1.1), the differentials of the coordinates dx^i are transformed by linear homogeneous transformations which constitute the affine group. Therefore the infinitesimal region surrounding an arbitrary point is regarded as an infinitesimal affine space. A space with affine connection is one in which there exists a law of correspondence or mapping of regions surrounding two adjacent points, and in 1918 Weyl⁽³⁷⁾ showed that to obtain such a space we need a parallel displacement of vectors. Given a contravariant vector ξ^i at a point P , the differential equations

$$d\xi^i + \Gamma_{jk}^i \xi^j dx^k = 0, \quad (2.1)$$

which are linear in ξ^i and dx^k , define a law by means of which the vector is given a *parallel* displacement to an infinitely nearby point in the direction dx^k . Since the law has to be invariant under transformations (1.1), the functions Γ_{jk}^i are coefficients of affine connection defined by (1.2). If however we want to transport the vector from P to a point Q which is at a *finite* distance from P , we have to choose arbitrarily a curve C joining P and Q and then transport the vector by infinitesimal steps from point to point along C . The vector which is obtained at Q depends, in general, not only on the original vector at P but also on the curve C along which the vector is transported. The essential features of a parallel displacement are: (i) If the vector ξ^i is moved by (2.1) round an infinitesimal parallelogram $(dx, \delta x)$, the change $\Delta\xi^i$ in the components ξ^i is given by

$$\Delta\xi^i = B_{jkl}^i \xi^j dx^k \delta x^l,$$

where

$$B_{jkl}^i = \frac{\partial \Gamma_{jl}^i}{\partial x^k} - \frac{\partial \Gamma_{jk}^i}{\partial x^l} + \Gamma_{sk}^i \Gamma_{jl}^s - \Gamma_{sl}^i \Gamma_{jk}^s. \quad (2.2)$$

And since this operation has to be invariant, it follows that B_{jki}^i is a tensor. This tensor, which is called the 'curvature tensor' with respect to (2.1) plays an important part in the theory of space⁽²¹⁾. (ii) The equations (2.1) give rise to a process of differentiation called 'covariant differentiation'.

having the property that the covariant derivative of a tensor is a tensor. If, for example, T_j^i is a tensor and if the covariant derivative with respect to (2.1) is denoted by a comma, then

$$T_{j,k}^i = \frac{\partial T_j^i}{\partial x^k} + T_j^s \Gamma_{sk}^i - T_s^i \Gamma_{jk}^s. \quad (2.3)$$

As said at the outset, the theory of parallel displacement was originally formulated by Levi-Civita⁽¹⁵⁾ and the formulation was made in a Riemannian space. Riemannian geometry has its origin in the famous dissertation by Riemann⁽¹⁸⁾ in 1854. It was conceived as a generalisation of the ordinary differential geometry and it deals generally with those intrinsic properties which depend on the 'metric' of the space. The metric which provides a basis of measurement is given by a quadratic differential form

$$ds^2 = g_{ij} dx^i dx^j, \quad |g_{ij}| \neq 0, \quad (2.4)$$

where ds is the line element and g_{ij} are functions of the coordinates. The well-known equations of Levi-Civita parallelism are given by (2.1) when the quantities Γ_{jk}^i are replaced by the Christoffel symbols $\{i_k\}$ formed from the symmetric tensor g_{ij} . This parallelism has an Euclidean connection which may be explained as follows: Let S be an ordinary surface embedded in a 3-dimensional Euclidean space, P and Q be two points of S , and C be a curve of S joining P and Q . Further, let ξ be a vector tangential to S at P and η be the vector at Q parallel to ξ in the sense of Levi-Civita. If D is the developable surface which touches S along C and if D is developed on a plane, then ξ and η becomes parallel in the plane in the Euclidean sense. The essential features of Levi-Civita parallelism may be stated as follows: (i) If C is a geodesic of the space, the parallels ξ and η make the same angle with C . It follows that geodesics are autoparallels. (ii) The covariant derivative of the metric tensor g_{ij} with respect to Levi-Civita parallelism vanishes. It follows that the scalar product of two vectors remains unaltered by Levi-Civita parallelism. (iii) The curvature tensor R_{jkl}^i at a point formed as in (2.2) by replacing Γ_{jk}^i by $\{i_k\}$ is intimately connected with the curvature of the space at the point in the orientation in which the infinitesimal parallelogram is taken. As a matter of fact, the angle between the initial and final positions of a vector which is carried by Levi-Civita parallel transport round a simple closed curve on a surface S is equal to the total curvature of the region of S enclosed by the curve.

In 1918 Weyl⁽³⁸⁾ proposed a geometry which rests on the assumption that the metric tensor of the space is determined to within a factor of proportionality called the 'gauge'. It is only when the gauge is definitely fixed that the space behaves like a metric space. In such a space Weyl introduced a parallel displacement having the following property: For a particular

choice of g_{ij} , let ϕ denote the scalar product of two vectors at a point; then, when the vectors are carried by the infinitesimal parallel transport to an adjacent point, the ratio $d\phi : \phi$ depends only on the points and not on the particular vectors chosen. Denoting this ratio by $-dw$, we get his characteristic equation

$$(g_{ij})_k + g_{ij}w_k = 0, \quad w_k = \frac{\partial w}{\partial x^k}, \quad (2.5)$$

where the bracket denotes covariant derivative with respect to his parallelism. Weyl also assumed that the coefficients Γ_{jk}^i of his connection were symmetric in j, k . It therefore follows from (2.5) that

$$\Gamma_{jk}^i = \{i_k\} + \frac{1}{2}[\delta_j^i w_k + \delta_k^i w_j - g_{jk}w^i], \quad (2.6)$$

where δ_j^i are the Kronecker deltas. The autoparallels with respect to (2.6) have a significance independent of the gauge. Cartan⁽⁴⁾ uses the terms 'with torsion' and 'without torsion' for the non-symmetric and symmetric connections respectively by giving a geometrical meaning of torsion of space.

3. GEOMETRY OF PATHS

In 1922 Veblen and Eisenhart⁽³¹⁾ discovered what is known as the geometry of paths. Here the space is supposed to be full of given curves, called paths, which are defined as the solutions of a system of differential equations

$$\frac{d^2 x^i}{ds^2} + \Gamma_{jk}^i \frac{dx^j}{ds} \frac{dx^k}{ds} = 0, \quad (3.1)$$

where, since the second term in (3.1) is a quadratic form, there is no loss of generality in taking Γ_{jk}^i as symmetric. In this conception, the path, rather than the parallel displacement, is taken as the fundamental notion. But as the equations (3.1) are simply the equations of autoparallels, the analytical theory which results from this conception is equivalent to that of the affinely connected space with symmetric connection. In general the same set of paths is specified by more than one set of coefficients Γ_{jk}^i . The study of those properties of paths which depend only on the paths and not on a particular set of coefficients constitutes the projective geometry of paths⁽³⁰⁾. The equations (3.1) define the same set of paths as the equations obtained from them by replacing Γ by $\bar{\Gamma}$ and s by $\bar{s}$ provided that

$$\bar{\Gamma}_{jk}^i = \Gamma_{jk}^i + \delta_j^i \psi_k + \delta_k^i \psi_j \quad \text{and} \quad \frac{d\bar{s}}{ds} / \left(\frac{ds}{d\bar{s}}\right)^2 = -2\psi_k \frac{dx^k}{d\bar{s}}, \quad (3.2)$$

where ψ_j is any vector. Each vector ψ_j leads to a different affine connection, but the quantities

$$\Pi_{jk}^i = \Gamma_{jk}^i - \frac{1}{n+1} (\delta_j^i \Gamma_{ik}^l + \delta_k^i \Gamma_{il}^j) \quad (3.3)$$

have the same values for all affine connections; they are called 'components of projective connection'. The curvature tensor however belongs to affine geometry and not to projective; but Weyl⁽³⁹⁾ found a 'projective curvature tensor'.

If I do not attempt to describe the significant researches made in recent years in the geometry of paths by Kosambi⁽¹⁴⁾, it is because they are beyond the scope of this address.

4. TELEPARALLELISM

We have seen in § 2 that in the general affinely connected space it is of no significance to say that a vector at a point is parallel to a vector at a distant point unless the curve along which the vector is transported is taken into consideration. Given the equations (2.1) of a parallelism, Cartan⁽³⁾ seems to be the first to have noticed in 1923 that the condition that these equations may be unconditionally integrable, i.e., the parallelism is independent of the curve of transport, is that the curvature tensor B_{kl}^i defined by (2.2) should identically vanish. Weitzenbock⁽³⁶⁾ solved the equations $B_{jkl}^i = 0$ in Γ_{jk}^i , and the solution may be stated thus: Let h_a^i be n^2 arbitrary functions satisfying $|h_a^i| \neq 0$, and let h_a^i be their reciprocal functions. Then the solution is given by

$$\Gamma_{jk}^i = h_a^i \frac{\partial h_j^a}{\partial x^k}. \quad (4.1)$$

This solution established the existence of parallelism having the property that given a vector at any point, there exists at any other point a *unique* vector which is parallel to it. This kind of parallelism is called a distant parallelism or a *teleparallelism*. To get a geometrical idea, consider the configuration consisting of n independent vector fields h_a^i for $\alpha = 1, \dots, n$, and let the vectors of the configuration at each point be used to define a local coordinate system at the point. Then two vectors are said to be parallel if their corresponding components are equal when referred to the local system of coordinates. The local system is not however completely determined by the teleparallelism. They may be replaced by linear combinations of h_a^i with constant coefficients having non-vanishing determinant.

The problem of introducing metric determination in the above space of teleparallelism was studied by Bortolotti⁽²⁾ and others. The problem

can be expressed thus: Given a non-symmetric parallel transport (2.1), what is the condition that the length of a vector should remain unaltered by this transport? This question introduces a metric and it is seen that the condition is given by the equations $g_{ij;k} = 0$. Further, the condition that these equations should be consistent is that $g_{ht}B_{jkl}^i + g_{ij}B_{hkl}^t = 0$, which is satisfied when the given parallelism is a teleparallelism. Therefore to find the metric of a space which is compatible with a given teleparallelism (4.1), we have to solve the differential equations $g_{ij;k} = 0$, where the solidus denotes covariant derivative with respect to the teleparallelism. The solution is given in the normalised form by

$$g_{ij} = \sum_{\alpha} h_i^{\alpha} h_j^{\alpha}. \quad (4.2)$$

The equations (4.2) show that the h 's are unit vectors which are mutually orthogonal, *i.e.*, they form an orthogonal ennuple. It follows that two parallel vectors make the same angles with the vectors of the ennuple and are equal in length. Einstein⁽⁸⁾ in his unified field theory of 1928 made use of this metric space (4.2) of teleparallelism (4.1).

Euclidean parallelism is obviously a teleparallelism, and the simplest kind of space after the Euclidean space is a space of non-zero constant curvature. As is well-known, there are two types of such spaces, one compatible with the parallelism of Bolyai and Lobachevsky and the other with the two kinds of parallelisms of Clifford. Clifford's parallelisms however exist in a 3-dimensional elliptic space. In 1929 Whittaker⁽⁴⁰⁾ noticed that the equations of Lobachevskian parallelism were not linear and so could not be expressed in the form (2.1), but Clifford's parallelisms, which are of course teleparallelisms, could be so expressed. He gave their differential equations which may be stated as follows: Writing for the moment the space coordinates as x_i instead of as x^i , $i=1, 2, 3$, take the Riemann form of the metric tensor of a 3-dimensional space of constant curvature l^2 :

$$g_{ii} = 1 / \left(1 + \frac{1}{4} l^2 \theta \right)^2, \quad g_{ij} = 0 \quad (i \neq j), \quad \text{where } \theta = x_1^2 + x_2^2 + x_3^2$$

In this space take the following pair of orthogonal ennuples h_a^i :

$$\left. \begin{aligned} h_1^1 &= 1 + \frac{l^2(2x_1^2 - \theta)}{4}, & h_1^2 &= \frac{l^2 x_1 x_2}{2} \pm l x_3, & h_1^3 &= \frac{l^2 x_1 x_3}{2} \mp l x_2, \\ h_2^1 &= \frac{l^2 x_1 x_3}{2} \mp l x_3, & h_2^2 &= 1 + \frac{l^2(2x_2^2 - \theta)}{4}, & h_2^3 &= \frac{l^2 x_2 x_3}{2} \pm l x_1, \\ h_3^1 &= \frac{l^2 x_1 x_3}{2} \pm l x_2, & h_3^2 &= \frac{l^2 x_2 x_3}{2} \mp l x_1, & h_3^3 &= 1 + \frac{l^2(2x_3^2 - \theta)}{4} \end{aligned} \right\} \quad (4.3)$$

where the two ennuples of the pair correspond to the upper and the lower sign in (4.3). Then the pair of Clifford's parallelisms are given by (4.1) where the h 's have the values given in (4.3).

5. CONNECTION OF TELEPARALLELISM WITH DISPLACEMENT OF SPACE

Investigations on displacement of space, particularly those which are connected with teleparallelism, were made by Bianchi⁽¹⁾, Eisenhart^(9,11), Cartan, Schouten, Robertson⁽¹⁹⁾ and others using the ideas of continuous transformations expounded by Lie⁽¹⁶⁾ and Killing⁽¹³⁾. Lie introduced the notion of an r -parameter group G_r of transformations. According to Lie's theory, if the n infinitesimal transformations $x'^i = x^i - \xi_\alpha^i \delta t$ given by $\alpha = 1, \dots, n$, where ξ_α^i are n^2 independent functions of x^i , generate of simply transitive group G_n ($r = n$), then the equations

$$\xi_\alpha^j \frac{\partial \xi_\beta^i}{\partial x^j} - \xi_\beta^j \frac{\partial \xi_\alpha^i}{\partial x^j} - c_{\alpha\beta}^\lambda \xi_\lambda^i = 0, \quad (5.1)$$

where $c_{\alpha\beta}^\lambda$ are constants, are satisfied identically. Further, if the functions ζ_α^i are similarly used to generate another simply transitive group H_n , then the conditions that each transformation of G_n is commutative with each transformation of H_n is that the equations

$$\xi_\alpha^j \frac{\partial \zeta_\beta^i}{\partial x^j} - \zeta_\beta^j \frac{\partial \xi_\alpha^i}{\partial x^j} = 0 \quad (5.2)$$

are satisfied identically. Two such groups are said to be reciprocal. Suppose now the space is linearly connected and $\Gamma_{jk}^i = \xi_\alpha^i \partial \xi_\alpha^a / \partial x^j \partial x^k$ are the coefficients of a teleparallelism in the space. Then a necessary and sufficient condition that the vectors ξ_α^i determine a simply transitive group, i.e., satisfy (5.1), is that there exists a second teleparallelism with coefficients of connection, say $L_{jk}^i = \zeta_\alpha^i \partial \zeta_\alpha^a / \partial x^j \partial x^k$, such that

$$\Gamma_{kj}^i = L_{jk}^i. \quad (5.3)$$

And when this condition is satisfied the vectors ζ_α^i also determine a simply transitive group and the two groups are reciprocal, i.e., satisfy (5.2).

In a Riemannian space with metric (2.4), Killing showed that a necessary and sufficient condition that an infinitesimal transformation $x'^i = x^i + h^i \delta t$ should leave the metric invariant is that the equations

$$h_{ij} + h_{ji} = 0, \quad (5.4)$$

where semi-colon denotes covariant derivative with respect to Levi-Civita parallelism, must be satisfied. And when these equations are satisfied, the space admits a group of motions. This is a generalisation of the group of rigid motions in Euclidean geometry. Further, in Euclidean parallelism, to any family of parallel lines there corresponds a translation in which parallel lines are conserved. For a generalisation of this property, consider a teleparallelism in a Riemannian space and take a family of parallel vectors with respect to this parallelism. Then the condition that there should exist infinitesimal rigid motion of the whole space in which each point moves along a parallel is that the autoparallels with respect to the teleparallelism should be geodesics of the space.

In 1932 Cartan⁽⁵⁾ introduced a type of Riemannian spaces, called *symmetric spaces*, which admit a kind of rigid displacement (symmetry) for which the Levi-Civita parallelism conserves Riemannian curvature. His idea may briefly be explained thus: Consider a transformation of points in the neighbourhood of a point θ which transforms a point P to a point P' such that θ is the middle point of the geodesic arc PP' , the points P and P' being called symmetric with respect to θ . Under this transformation, to every vector ξ issuing from P there corresponds a definite vector ξ' issuing from P' which is symmetric to ξ . Then the vector ξ'' at P' which is equal and opposite to ξ' is the vector that is said to be obtained by transporting the vector ξ by symmetry. Cartan has shown that if this transport by symmetry is to be the same as transport by Levi-Civita parallelism along the arc of a geodesic, then the covariant derivative of Riemann-Christoffel tensor must vanish identically, *i.e.*,

$$R_{hijk;l} = 0. \quad (5.5)$$

All Riemannian spaces for which (5.5) is satisfied are called symmetric spaces. A space of constant curvature is evidently a symmetric space and it is the simplest of such spaces.

All the properties of infinitesimal transformations mentioned above are satisfied by the pair of orthogonal ennuples (4.3) which determine Clifford's parallelisms. As a matter of fact, Clifford's parallelisms in a 3-dimensional space of constant curvature are characterised by the properties (5.3) and (5.4), *i.e.*, by

$$\Gamma_{kj}^i = L_{jk}^i, \quad \frac{1}{2}(\Gamma_{jk}^i + \Gamma_{kj}^i) = \{_{jk}^i\}. \quad (5.6)$$

Quite recently an attempt has been made by Sen⁽²⁸⁾ to construct a type of 3-dimensional Riemannian spaces which may be considered as a generalisation of 3-dimensional spaces of constant curvature arising from a generalisation of Clifford's parallels. Writing for the moment x_i instead x^i ($i = 1, 2, 3$), if $\chi = \chi(\theta)$ is any real analytical function of $\theta = x_1^2 + x_2^2 + x_3^2$ which

may, in particular, be a constant $\neq 0$, and $l \neq 0$ is any constant, then the pair of orthogonal ennuples h_α^i giving this generalisation can be defined by

$$\left. \begin{aligned} h_1^1 &= \frac{2\chi^2}{\theta} x_1^2, \quad h_1^2 = \frac{2\chi^2}{\theta} x_1 x_2 \pm l x_3, \quad h_1^3 = \frac{2\chi^2}{\theta} x_1 x_3 \mp l x_2, \\ h_2^1 &= \frac{2\chi^2}{\theta} x_1 x_2 \mp l x_3, \quad h_2^2 = \frac{2\chi^2}{\theta} x_2^2, \quad h_2^3 = \frac{2\chi^2}{\theta} x_2 x_3 \pm l x_1, \\ h_3^1 &= \frac{2\chi^2}{\theta} x_1 x_3 \pm l x_2, \quad h_3^2 = \frac{2\chi^2}{\theta} x_2 x_3 \mp l x_1, \quad h_3^3 = \frac{2\chi^2}{\theta} x_3^2 \end{aligned} \right\} \quad (5.7)$$

the two ennuples of the pair corresponding to the upper and the lower sign in (5.7). It is seen that, with reference to (5.7), the two sets of coefficients of the teleparallelisms satisfy the property

$$\frac{1}{2}(\Gamma_{jk}^i + L_{jk}^i) = \{i_k\}, \quad (5.8)$$

which may, for the purpose of comparison with (5.6), be written as

$$\frac{1}{2}(\Gamma_{kj}^i - L_{jk}^i) = \frac{1}{2}(\Gamma_{jk}^i + \Gamma_{kj}^i) - \{i_k\}. \quad (5.9)$$

Further, the space (4.2), where h_α^i have the values given in (5.7), is a symmetric space but not a space of constant curvature. It seems worthwhile to study the nature of the transformations generated by the vectors (5.7), although these transformations do not form a group. As a matter of fact, if the left-hand members of (5.1) and (5.2) are denoted by A and B , these vectors satisfy the equations $A - B = 0$.

6. FIELD OF PARALLEL PLANES

In recent years, the theory of parallel fields of vector spaces, or of parallel planes as it is generally called, in Riemannian spaces and with reference to Levi-Civita parallelism has been developed by quite a number of mathematicians, particularly by Eisenhart^(10, 12) Ruse^(20, 22) and Walker^(32, 33, 34). Denoting an n -dimensional Riemannian space whose metric is not necessarily positive-definite by V_n and the n -dimensional vector space formed by the totality of vectors, including null vectors (*i.e.*, vectors of length zero), at a point of V_n by V^n , the theory is concerned with the existence of parallel subspaces of V^n at points of V_n . To understand the theory, we have initially to take account of the nature of V^n which may be described as follows: Any orthogonal basis of V^n is a set of n orthogonal non-null vectors; but any orthogonal basis of a subspace V of V^n may contain null vectors. If it does, then every orthogonal basis of V contains the same number, say r , of null vectors, called the nullity of V , and $r \leq n/2$. The vector space V' generated by these r null vectors is called the null part of V . If V is of dimension m

and W be the vector space of dimension $n-m$ which is orthogonal to V , then V and W are called conjugate and they intersect in V' which is also the null part of W . If V consists of null vectors only, it is called null. In what follows a vector space of dimension m will be called an m -plane.

A field of m -planes is a set of m -planes, one at each point of V_n , whose bases are m independent fields of vectors, say ξ_α^i , $\alpha = 1, \dots, m$. This field is said to be *parallel* if, for two points P and Q , a vector in the plane at P is displaced into a vector in the plane at Q by Levi-Civita parallel displacement along *any* curve whatever from P to Q . Walker⁽³²⁾ has shown in 1949 that a necessary and sufficient condition that a field of m -planes with bases ξ_α^i be parallel is that for some functions (vectors) $A_{\alpha j}^\beta$

$$\xi_{\alpha;j}^i = A_{\alpha j}^\beta \xi_\beta^i, \quad i, j = 1, \dots, n; \quad \alpha, \beta = 1, \dots, m, \quad (6.1)$$

where semi-colon denotes covariant derivative with respect to Levi-Civita parallelism. It follows that if there exists a field of parallel planes, then the field of their null parts and the field of their conjugates are also parallel. And if there exist two fields of parallel planes, then the fields of their meet and join are also parallel.

An orthogonal basis is said to be normal if the non-null vectors in the basis are unit vectors. A normal basis of V^n is therefore an orthogonal ennuple. Wong⁽⁴¹⁾ in his study of an invariant theory with vectors, including null vectors, constructed a quasi-orthogonal ennuple consisting partly of null and partly of non-null vectors as a basis of V^n . Using a suitable quasi-orthogonal ennuple $\xi_1^i, \dots, \xi_n^i$ and applying the condition (6.1) of parallel planes, Ruse⁽²²⁾ has examined in 1950 the general case of a parallel $(r+s)$ -plane of nullity r . He has shown, in particular, that the cases (i) n even, $r = \frac{1}{2}n-1$, $s = 0$ or 1 and (ii) n odd, $r = \frac{1}{2}(n-3)$, $s = 1$ possess exceptional features. As an instance, one of his theorems for case (i) is as follows: When n is even and V_n admits a null parallel $(\frac{1}{2}n-1)$ -plane, it also admits two null parallel $\frac{1}{2}n$ -planes intersecting in the given $(\frac{1}{2}n-1)$ -plane. These planes are all contained in the parallel $(\frac{1}{2}n+1)$ -plane of nullity $\frac{1}{2}n-1$ conjugate to the given $(\frac{1}{2}n-1)$ -plane.

An abstract algebraic background of the properties of parallel planes that have so far been described above has been given by Sen⁽²⁹⁾ by choosing a suitable set of axioms. These axioms define the product of vectors, the nature of the algebraic field over which the vector space is taken and a certain notion of invariance of the subspaces. The treatment rests on certain well-known properties of matrices over a field.

One of the most difficult contributions to the theory of parallel planes is that which gives the canonical forms of metrices of V_n 's admitting different kinds of parallel planes. Eisenhart⁽⁴²⁾ has given the canonical form

in the case of a V_n admitting a strictly parallel s -plane, i.e., a system of s independent parallel vectors. The most general result in this respect has been obtained by Walker⁽³⁴⁾ who has given the canonical form for a V_n which admits a parallel $(r+s)$ -plane of nullity r . Using the theory of complete system of partial differential equations, he has shown that there exists in such a V_n a coordinate system for which the basis vectors of the parallel plane are given by the Kronecker deltas $\{\delta_\alpha^i\}$ and that in this coordinate system the matrix $[g_{ij}]$ of the fundamental tensor can be expressed in terms of submatrices as

$$\begin{bmatrix} 0 & 0 & 0 & I \\ 0 & A & 0 & F \\ 0 & 0 & B & G \\ I & F' & G' & C \end{bmatrix}. \quad (6.2)$$

where I is the unit matrix, dash denotes the transpose and the non-zero submatrices, whose orders are given by the partition of n into $n = (r) + (r) + (s) + (n - 2r - s)$ for both rows and columns, satisfy certain specified conditions.

In 1953 Wong⁽⁴²⁾ considers parallel planes in an affine space A_n with a symmetric connection. In A_n a parallel plane of contravariant vectors is defined by the same equations as (6.1) except that the covariant derivative is now taken with respect to the symmetric connection instead of with respect to Levi-Civita parallelism. Wong has shown that if A_n admits two parallel planes π and π' , then there exists in A_n a coordinate system for which their bases are provided by Kronecker deltas. He then applies his result to the case when A_n is a V_n , π is an $(r+s)$ -plane of nullity r and π' the conjugate of π and shows that this leads to Walker's result as stated above.

Again in 1953 Patterson⁽⁴⁷⁾ applies the notion of parallel planes to characterise Kähler's manifolds. The nature of his complex analytic structure is as follows: Let P be any point of a manifold M_n of class C^r ($r \geq 2$) and N, N' any two coordinate neighbourhoods of P , parametrised by real coordinates x^i and x'^i respectively. Associate with P and N complex numbers ξ^i and with P and N' complex numbers ξ'^i ($i = 1, \dots, n$). Then the transformations $\xi'^i = \xi^j \partial x'^i / \partial x^j$ define a complex contravariant vector. The set of all complex contravariant vectors at P having their components in a neighbourhood becomes an n -dimensional vector space M^n over the complex field. A complex m -plane p^m at P ($m \leq n$) is an m -dimensional subspace of M^n , and any set of linearly independent vectors of p^m forms one of its bases. It is clear that M^n admits a real basis, but p^m may or may not contain real vectors other than the zero vector. If it does, then it contains one or more real planes. The complex conjugate $\bar{p}^m$ of p^m is

the set of complex contravariant vectors whose components are the complex conjugate of those of the vectors of p^m . The meet of p^m and $\bar{p}^m$ admits a real basis. A set of m -planes, one defined at each point of M_n , is a field of complex m -planes. In N let ξ_α^i ($\alpha = 1, \dots, m$) be a basis of p^m , where the ξ 's are complex functions of $x^1, \dots, x^n$. Given a real symmetric affine connection Γ in M_n , the field p^m is said to be parallel with respect to Γ if and only if the ξ 's satisfy Walker's equations (6.1), where the semi-colon now denotes covariant derivative with respect to Γ and $A_{\alpha j}^\beta$ are components of complex covariant vectors. It follows that if a field is parallel, its complex conjugate is also parallel.

Suppose now $n = 2r$. Then a complex coordinate system in N may be defined by

$$z^\alpha = x^\alpha + ix^{\alpha'}, \quad \alpha = 1, \dots, r; \quad \alpha' = \alpha + r. \quad (6.3)$$

(Greek indices run from 1 to r and primed Greek indices run from $r+1$ to $2r$). Transformations of real coordinate systems in the overlapping regions of coordinate neighbourhoods give rise to transformations of the corresponding complex coordinate systems and thereby M_{2r} may be made to admit a complex analytic structure. A positive definite Riemannian metric g_{ij} is now introduced in M_{2r} . This metric is called Hermitian if its components in a complex coordinate system is given by

$$[g_{ij}] = \begin{bmatrix} O & A \\ A' & O \end{bmatrix}, \quad (6.4)$$

where $A = [g_{\alpha\beta'}]$, A' is the transpose of A and its complex conjugate $\bar{A}' = A$. A skew symmetric tensor h_{ij} is then defined by replacing A' by $-A'$ in (6.4). The sum $p_{ij} = g_{ij} + h_{ij}$ is a complex tensor which is used to define a field π^r of r -planes. It is defined by the solutions ξ^i of the equations $p_{ij}\xi^j = 0$. It is seen that π^r is null. An Hermitian metric is said to be Kählerian if in every complex coordinate system

$$\frac{\partial g_{\alpha\beta'}}{\partial z^\gamma} = \frac{\partial g_{\gamma\beta'}}{\partial z^\alpha}. \quad (6.5)$$

Patterson proved the theorem that an Hermitian manifold M_{2r} is a Kähler manifold if and only if the above field π^r is parallel with respect to Christoffel symbols of the manifold.

7. K*-SPACES

An interesting type of spaces have quite recently (1949-51) been discovered and studied in details by Ruse^(21,23) and Walker⁽³⁵⁾ which admit

certain kinds of parallel vector fields. These spaces are defined as follows: If the Riemann Christoffel tensor R_{hijk} of a non-flat V_n satisfies the equations

$$R_{hijk;l} = R_{hijk}\kappa_l \quad (7.1)$$

for some non-zero vector κ_l or else the equations

$$R_{hijk;l} = 0, \quad R_{hijk}\kappa_l + R_{hikl}\kappa_j + R_{hilj}\kappa_k = 0, \quad (7.2)$$

then it is called a K_n^* -space or simply a K^* -space. A K^* -space is called recurrent (in the sense of Ruse) or symmetric (in the sense of Cartan) according as it satisfies (7.1) or (7.2). A V_2 is a K_2^* for which R_{hijk} satisfies a simple relation of the form

$$R_{hijk} = r_{hi}r_{jk}. \quad (7.3)$$

Ruse has established the existence of a class of K_n -spaces, $n \geq 2$, called *simple K^* -spaces*, for which R_{hijk} have the form (7.3), and he has obtained their canonical forms. Walker has given an alternative definition of a simple K^* -space. He first shows that every V_n which admits $n-1$ independent parallel vector fields is flat and so in fact admits n of them. He then defines a simple K^* -space as a V_n which admits the maximum number, i.e., $n-2$, of independent parallel vector fields. This definition leads to a certain characteristic of a simple K^* -space which may be explained as follows:

A V_n is said to be decomposable if it can be expressed as a product $V_r \times V_{n-r}$ for some r i.e., if coordinates can be found so that its metric takes the form

$$ds^2 = \sum_{i,j=1}^r g_{ij} dx^i dx^j + \sum_{k,l=r+1}^n g_{kl} dx^k dx^l, \quad (7.4)$$

where g_{ij} are functions of $x^1, \dots, x^r$ only and g_{kl} are functions of $x^{r+1}, \dots, x^n$ only. When one of the decomposition spaces, say V_{n-r} , is flat, V_n is called a flat extension of V_r . Walker has shown that a simple K_n^* is a flat extension of either a K_2^* (a V_2) or a K_3 or a K_4^* and he has shown that such a space satisfies Ruse's definition (7.3). Ruse has given a classification of K^* -spaces in which the simple K^* -spaces are made to depend on the Ricci tensor R_{ij} and the scalar curvature R . He has shown that the above three possibilities given by Walker can happen respectively in the following three cases: (i) $R \neq 0$. In this case all the $n-2$ parallel vector fields are non-null and they are perpendicular to κ_i . (ii) $R = 0$, but $R_{ij} \neq 0$. In this case one of the $n-2$ parallel vector fields is null. They are all perpendicular to κ_i if it is non-null; but if κ_i is null, the null parallel vector field is codirectional with κ_i and the others are perpendicular to it. (iii) $R_{ij} = 0$. In this case

two of the $n-2$ parallel vector fields are null and all are perpendicular to κ_i which is now null. When a K^* -space is non-simple, it admits a null parallel vector field cordirectional with κ_i which is now necessarily null. Ruse has given an interesting geometrical picture of the K^* -spaces. The geometrical background is a projective space associated with an arbitrary point of V_n and is based on the tangent space theory. Restrictions of time and space prevent me from attempting to describe the picture.

8. ALGEBRAIC SYSTEM OF AFFINE CONNECTIONS

In quite a different sphere investigations were published by Sen^(25, 26) in 1948-50 depicting the behaviour of an arbitrary parallel displacement in a Riemannian space V_n . If by an arbitrary parallel transport in a V_n with metric (2.4) the change in the contravariant components of a vector ξ^i is given by (2.1), then the change in the covariant components ξ_i of the same vector is given by the equations

$$d\xi_i = \Gamma_{ik}^t \xi_t dx^k \quad (8.1)$$

provided the length of the vector ξ remains unaltered by the parallel transport. The question therefore arises, what will be the equations if the length does not remain invariant? Denoting the covariant derivative with respect to (2.1) by a comma, the answer to the question is given by

$$d\xi_i = \Gamma_{ik}^{*t} \xi_t dx^k, \quad \text{where} \quad \Gamma_{ik}^{*t} = \Gamma_{ik}^t + g^{tl} g_{il,k}. \quad (8.2)$$

Conversely if (8.2) is given, (2.1) follows and therefore they represent the same parallelism. With the parallelism (2.1) we can therefore associate another parallelism given by

$$d\xi^i + \Gamma_{jk}^{*i} \xi^j dx^k = 0, \quad (8.3)$$

or its equivalent (8.1). Further, along with (2.1) we can consider still another parallelism obtained by interchanging the lower suffixes of Γ , namely

$$d\xi^i + \Gamma_{jk}'^i \xi^j dx^k = 0, \quad \text{where} \quad \Gamma_{jk}'^i = \Gamma_{kj}^i, \quad (8.4)$$

which is different from (2.1) unless Γ_{jk}^i is symmetric. These considerations together with the general nature of an affine connection lead to the following algebraical formulation:

Let an algebraic system S be generated by a single abstract element having the following properties:

(i) Corresponding to every element a of S there exist in S two elements called the associate and conjugate of a and denoted by a^* and a' respectively. They are governed by the involuntary property

$$a^{**} = a'' = a$$

(ii) A commutative composition is defined in S whereby every pair of elements a, b , of S is composed to form an element $a \circ b$ of S and the composition satisfies the idempotent and the cancellation laws:

$$a \circ a = a; \text{ and if } a \circ b = a \circ c, \text{ then } b = c.$$

(iii) The associate and the conjugate of $a \circ b$ satisfy

$$(a \circ b)^* = a^* \circ b^*, \quad (a \circ b)' = a' \circ b'.$$

An element of S which is equal to its associate is called self-associate shortly s.a. Similarly for a self-conjugate element, shortly s.c. The problem is to examine whether S contains an element which is both s.a. and s.c., and if so, to find such an element. The first part of this problem has been discussed by Chatterjee⁽⁷⁾ for a finite system only by considering σ, τ as the two generators, each of order two, of a group of finite order in which there exists a second composition ' $\circ$ ' (other than the group composition) such that the left-hand distributive law holds. He has given necessary and sufficient conditions for the existence of an element having the desired property. The second part of the problem has been solved by Sen⁽²⁶⁾ under the following special conditions: S does not contain more than one element which is both s.a. and s.c., and the following sequence generated by an arbitrary element a of S

$$a_1 = a, \quad a_2 = a^*, \quad a_3 = a^{**}, \quad a_4 = a^{***}, \dots \quad (8.5)$$

is a cyclic sequence of an even number, say p , of terms. Then, under certain circumstances, the element

$$a_i \circ a_{i+p/2} \quad (8.6)$$

is both s.a. and s.c. provided that $p/2$ is even.

The above algebraic system S has been applied in V_n by putting

$$a = \Gamma_{jk}^i, \quad a^* = \Gamma_{jk}^i + g^{il} g_{lj,k}, \quad a' = \Gamma_{k,i}^j, \quad b = L_{jk}^i, \quad a \circ b = \frac{1}{2}(\Gamma_{jk}^i + L_{jk}^i)$$

It is seen that all the properties of S mentioned above are satisfied, the sequence (8.5) being a cyclic sequence of 12 terms when a is arbitrary. Then applying (8.6) it is seen that the Christoffel symbol $\{\Gamma_{jk}^i\}$ is the element which is both s.c. and s.a. This is as is to be expected, because an s.a. parallelism is one with respect to which the covariant derivatives of g_{ij} 's vanish and an s.c. parallelism is one with symmetric connection, and Levi-Civita parallelism is the only parallelism which satisfies both these properties. The algebraic system has been further utilised⁽²⁷⁾ to construct newer elements possessing properties which have been applied to identify curvature tensors and discuss their relations. In this connection Chaki⁽⁶⁾ has obtained a number of interesting formulae by replacing Γ_{jk}^i by $\Gamma_{jk}^i + T_{jk}^i$, where T_{jk}^i is a tensor.

Geometry of the nature described in this section rests essentially on a symmetric tensor g_{ij} together with an affine connection Γ_{jk}^i , and one of the things which it implies is a system of affine connections, i.e., related parallelisms. In this related system the Levi-Civita parallelism having special property can always be identified. The situation therefore seems worthy of study as it includes the special Riemannian geometry which rests essentially on a symmetric tensor g_{ij} .

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SECTION OF STATISTICS

President : K. NAGABHUSHANAM, M.A., Fil.Lic., Dr.Fil.

Presidential Address

INFERENCE IN TIME SERIES

I deeply appreciate the honour which my colleagues have done me in electing me to the presidentship of the Section of Statistics of the Indian Science Congress this year, and I offer my grateful thanks to them. I shall endeavour my best to maintain the high tradition of my distinguished predecessors, and in this effort I solicit your kind co-operation.

2. BROAD-BASING OF EDUCATION

After the recent world war we have come to realize more than ever before that the present opportunity to build a peaceful world order should not be missed. For accomplishing this great work of social engineering, it is necessary to bring about a harmonious development of the individual. For this again, it is necessary to broad-base education at the lower grades and provide for specialized courses of study only at the higher stages. It is a happy circumstance that in the impending reorganization of education at the high school and the college, the idea of making education broad-based and general is receiving the careful attention of the authorities of the various universities in the country, as well as the Central and State Ministries of Education. Science students will hence-forth have to study some branches of the humanities, and arts students sciences in a general way. The scientific method will then become a part of the curriculum of study, not only for the science students, but also for the students of the humanities.

3. PROSPECT OF INCREASED STUDY OF STATISTICS

We are aware that Statistics is essentially the same as the scientific method. It is therefore likely that the subject of Statistics will come to be studied in increasing measure in the new educational set-up. The dissemination of statistical knowledge at different levels raises important issues which have to be tackled by pooling together the experience of the

teachers of Statistics. In this connection two main dangers need to be avoided. The first danger is that the student may not be properly initiated into the principles of the subject at the lower level. The second arises from a pursuit of only theory or practice to the exclusion of the other. The so-called professional training may, in the absence of a proper emphasis on the basic concepts of the subject, tend to become a mere collection of thumb-rules. The arithmetical and computational procedures, however necessary they may be, do not form the content of the subject. On the other hand, lack of emphasis on the practical aspects of the problem will hamper and cripple theoretical research. We know how the frontiers of knowledge in a subject are extended again and again when new practical situations present new problems, requiring for their solution fresh theoretical contributions to the subject.

4. DEFICIENCY MADE UP AT A HIGHER LEVEL

Statistics being the same as the scientific method, there will be naturally an incompleteness in the equipment of a statistician, if one or more of the subjects, in which statistical methodology plays a vital role, are not studied in addition to Statistics. At the present time this deficiency is made up to some extent in our Universities at the Honours and Post-graduate stages by the inclusion of subjects like Economics, Biology, and Life Insurance in statistical courses of study. There are also indications here and there that statisticians will be making a more intensive study of other sciences than at present. A complementary trend is also evident at the present time, viz., that of scientific workers in other subjects seeking a deeper understanding of the significance of inductive inference of statistics.

5. STATISTICAL RESEARCH

I shall now pass on to statistical studies at the research level. The degree of specialization in statistical research is growing at a rapid rate. It is difficult to make a comprehensive survey of the current trends in research, and to envisage the outlook for the future.

6. INFERENCE IN TIME SERIES

I have therefore set myself the less ambitious task of placing before you some of the current trends in research in the limited domain of Inference in Time Series.

Thinking in general terms about a problem frequently unfolds a picture suggestive of fruitful lines of attack. I therefore seek your permission to venture to give a general description of some of the possible mental

processes of a few workers who are now engrossed in the study of certain aspects of statistical inference in time series analysis.

7. EARLIER WORK ON TIME SERIES

Several common types of observational data belong to the class known as time series. The data consists of one or more series of magnitudes arranged in order of time. Sometimes we have a continuous record of observations, and at other times the record is a sequence (or sequences) of magnitudes observed at time instants spaced at equal intervals. In scientific literature these two types are distinguished by being referred to as the continuous and the discrete time series. As examples of the two types, we may mention respectively a continuous record of temperature and weekly prices relating to a particular commodity in a given market. Geophysical and meteorological time series can be observed over a long period, the annual conditions of weather remaining more or less the same over this long stretch of time. However, when the time series refers to an economic phenomenon, it is only rarely possible to obtain (or construct) a long series without a gap, because economic conditions undergo abrupt changes now and then.

A time series may be classified under the two heads: evolutive and stationary. It is conventional to analyse a time series into trend, cyclical part and the residual. Since no examination of the structure of the residual is made in this analysis, it must be said to be superficial. Nevertheless, it serves the purpose in many cases. Much of the existing work relates to the techniques of trend-fitting and periodogram construction. Tests of significance have also been considered in connection with time series analysis. G. Tintner's test [1] for the elimination of trend by the variate difference method, R. A. Fisher's test [2] of significance in harmonic analysis, and von Neumann's test [3] for auto-correlation of series are three such outstanding instances. Some work has been done on non-parametric inference in time series. This is mostly based on the distribution of runs and of rank correlation coefficient. In a few cases the problem of construction of confidence bands in estimation of functions has also been studied.

Many of the previous studies depend naturally on a consideration of time series from the standpoint of stochastic processes, whether explicitly mentioned or not. In this view a time series is just one sample series obtained from out of a population of possible time series any of which could have occurred in our work. Adopting this point of view, H. Wold [4] has carried out a study of stationary time series of the discrete parameter. The procedure of inference adopted here is somewhat subjective in that one proceeds to classify the time series as having been generated by an autoregressive process or a moving average process by judging from the appearance of

the empirical correlogram of the series its nearness to one or the other of the theoretical correlograms of the two types.

Turning to earlier work on economic time series, we find that statistical analysis of it was mainly confined to estimation of correlation coefficients and fitting of regression equations. For the first time it was pointed out by R. Frisch [5] that it is necessary to make sure that a regression equation makes sense before one actually fits the regression. Though a coefficient is really indeterminate, it will have a spurious determination in a sampling study. To steer clear of such pitfalls, the technique of Bunch Map analysis has been developed by him.

8. BASIS FOR SOME OF THE CURRENT WORK

Though I do not propose to go into the formal aspects of stochastic processes, I shall very briefly refer to some details with a view to show how the time became ripe by 1947 for the introduction of the classical procedures of statistical inference into time series studies. The work of A. Kolmogoroff [6], and J. L. Doob [7] has validated the use of a probability measure in respect of the population of time series (of sequences or of functions as the case may be) in a number of cases, if not universally. H. Cramér's spectral representation [8] of a stationary process and the subsequent work of K. Karhunen [9] on the Hilbert Space of a stochastic process have provided new and powerful tools for the study of time series from the point of view of stochastic processes..

There are two ways of looking at a stochastic process, viz. as a population of functions (or sequences), and alternatively as a collection of stochastic variables. In any attempt to introduce the classical procedures of statistical inference into the analysis of time series, one has to decide which of the two views is better suited to the situation on hand. Any time series may be considered as extending to infinity in both directions of time. Such a full series constitutes a single sample series. If at each time instant the observation is regarded as a value of a stochastic variate at that instant, a single sample series (or a realization as it is usually called) is just one observation on an infinite dimensional stochastic variate. Thus, an infinite number of stochastic variates are simultaneously under consideration. Whenever we find it convenient to adopt the view that the process is a population of stochastic variables, and employ linear methods in our analysis, we shall be naturally led to a consideration of the Hilbert Space formed by the linear combinations of these stochastic variables and their limit elements.

9. ESTIMATION IN TIME SERIES

(a) *Method of Maximum Likelihood :*

In studying any phenomenon, we do not impose restrictions, more than necessary. Frequently, the specification of time series does not go

beyond the stationarity, or the Markoff property. Only sometimes the normality of the variables is assumed. Due to this limited specification and the consequent lack of information for an explicit functional formulation of the likelihood, we find that the method of maximum likelihood is not ordinarily employable in estimation problems in time series analysis. It therefore becomes necessary to think of ways and means of carrying over estimation procedures based on the criteria of consistency, unbiasedness and minimum variance into time series work. The problem of estimation in time series has been studied in a more or less systematic manner for the first time by U. Grenander [10] in 1950.

The problem of carrying over the concept of likelihood into time series does not in itself present any essential difficulty which is peculiar to time series. As has been mentioned, the main difficulty is that of the insufficiency of specification for the determination of the explicit form of the likelihood. Of course, there is the question whether the likelihood function tends to a limit when the observations extend to infinity in one or both directions of time. However, this in itself is not an impediment, because our study relates, almost invariably, only to a truncated realization, though the series may be quite long. It is usual to specify a process by its covariance function (or covariance sequence). Without the assumption of normality one cannot progress much—a situation which has to be reckoned with on account of the fact that a good number of processes are not Gaussian. Besides this, a problem in time series is generally beset with another important limitation inherent in the nature of time. Whenever the parameter t is actually the time variable, the sample almost as a rule consists of only one element, as it is not possible to obtain simultaneously a number of different records. When the variable t is only a conventional time parameter and refers in reality to a variable such as the distance in a given direction, it is possible to obtain a number of realizations simultaneously referring to the same phenomenon. This situation corresponds to the usual case of a sample of size n . The problem of movement of pebbles at the bottom of a water canal has been studied by Einstein Jr. [11]. In this case, the phenomenon is specified to be a Poisson process, distance along the canal now becoming the conventional continuous time parameter. If the movements of n stones are independently observed, we get a sample of n realizations. Under suitable assumptions the maximum likelihood estimate of the mean resting time of the pebbles has been worked out by U. Grenander [10].

(b) *Criteria of Consistency, Unbiasedness and Minimum Variance :*

The usual criteria of consistency, unbiasedness, and minimum variance are directly transferable to time series studies. Corresponding to parameters of population we shall now have functions of time (or sequences ordered in time). For example, we may consider the mean value function of the process.

Suppose that this function is unknown, and we desire to estimate it from a single realization. Our estimate $m^*(t)$ will now be a function of the realization and thus a functional defined on the sample space. When the mean value function has a constant value, the problem becomes simpler. If this constant is unknown and is linearly estimated in terms of the observations, the condition of unbiasedness imposes a constraint which may be described in geometrical language as defining a hyper-plane. If the covariance of the process is known, the requirement of minimum variance reduces the problem to the determination of the coordinates of the point of contact of a quadric belonging to a given set of similar and similarly placed quadrics with the hyper-plane. We know that this problem has a unique solution.

Let us again consider a stationary process, i.e., a process for which :

1. the mean value function is constant,
- and
2. the covariance of the process variates for any lag depends only on that lag.

In this case, under the conditions of the mean ergodic theorem, the equi-distributed estimate (which is the time average of the recorded observations) is an unbiased and asymptotically efficient estimate of the unknown mean value. However, regarded as an estimate in terms of observations over a finite interval of time, the equi-distributed estimate is not necessarily the minimum variance estimate (see U. Grenander [10] p. 249, and K. Nagabhushanam [12] p. 113)

A problem of fundamental importance in inference in time series is the estimation of the covariances of the process for various lags. In all such cases a trend-eliminated series is considered, and it is specified that the mean value is zero. The observations are therefore deviations from the mean value of the process, so that the time average of the products of observations with a fixed lag is an unbiased estimate of the covariance for that lag. The consistency of such an estimate demands the convertibility of the time average limit into a space average. This can be secured only by making additional assumptions such as metric transitivity.

(c) *Prediction in Time Series :*

Prediction in time series (or prognosis, as it is otherwise called) is of great interest, because of its wide applicability in a number of fields. This being only a particular case of estimation, there is no need to make any general observations on this topic.

N. Wiener [13] has considered the following problem :

On a stationary series $f(t)$ which may be called the transmitted message a disturbance $g(t)$ gets superposed, and their mix-up is received at the other end of transmission. The message has now to be recovered by filtering out the disturbance as best as possible.

The problem is one of finding a linear operator, which when operating on the combined series, gives a resulting series which differs from the message at $t+h$ by the least possible extent. The solution of this problem requiring as it does the minimization of the variance of the error, depends on the solution of an integral equation.

If an unknown (primary) stationary process is linearly related in a known manner to another given stationary process, the problem of prediction of the primary process is a case of prediction with filtering as in the above problem of Wiener. If we denote the identity operator by E , and the operator in the linear relationship by L , we can regard L as the sum of the two operators $L-E$ and E . The result of the identity operation on the primary process is now the message part, and the result of the operation of $L-E$ on the process becomes the disturbance. In this case also, the criterion of minimum variance for the optimal prediction of the primary process brings us to an integral equation (see K. Nagabhushanam [14] p.478). I may mention that this integral equation is a necessary as well as sufficient condition for the error variance to be a minimum. Further, it is here proved that when the space average functions can be recast into time average functions, Levinson's form of Wiener's integral equation is deducible by a suitable specialization.

(d) *Estimation of the Spectrum :*

For a stationary process of the continuous parameter which is continuous in the mean, A. Khintchine [15] has shown that the covariance function $R(t)$ is the Fourier-Stieltjes transform of a bounded non-negative and non-decreasing function $\sigma(\lambda)$ of the real variable λ over $(-\infty, \infty)$, i.e.

$$R(t) = \int_{-\infty}^{\infty} e^{it\lambda} d\sigma(\lambda).$$

For a stationary process of the discrete parameter, the modification in the above representation will be that the range becomes $(-\pi, \pi)$ instead of $(-\infty, \infty)$, and the condition of continuity in the mean gets dropped out. The function

$$\sigma(\lambda) = \int_{-\infty}^{\lambda} d\sigma(\lambda) \quad \text{or} \quad \sigma(\lambda) = \int_{-\pi}^{\lambda} d\sigma(\lambda)$$

as the case may be, is called the integrated spectrum of the process, and is an epitome of the entire pattern of covariances of the process. Due to the fact that each point of discontinuity of $\sigma(\lambda)$ implies the existence of a corresponding periodicity, the estimation of the spectrum is a problem of fundamental importance in the analysis of stationary time series relating to a search for hidden periodicities.

A little reflection will make it clear that the classical periodogram analysis is in reality an estimation of the derivative of the absolutely continuous part of the spectrum which we shall hereafter refer to as the spectral density. In what follows I shall confine my attention to the case of a discrete stationary process, but it should be understood that this imposes no essential restriction.

One main difficulty in spectral estimation is that the spectral function involves all the covariances. The estimates of the covariances are subject to increasing sampling fluctuations as the lag increases. From such considerations M. S. Bartlett [16] has been led to a method of weighting the sequence of estimated covariances in a manner that as the lag increases the weight attached diminishes continually, so that in the estimate of the spectrum proposed by him, violent sampling fluctuations of the much lagged covariances are counteracted.

Even when the estimates of the covariances are consistent, the periodogram estimate of the spectrum is not consistent. The only point in favour of the periodogram is that it is an asymptotically unbiased estimate of the spectral intensity in the case of processes which have a continuous spectral density. Daniel has suggested the averaging of the periodogram over an extent of h on either side of the frequency λ under consideration. His suggestion seems to have been motivated by Khintchine's law of large numbers. Integrating over a neighbourhood and averaging will yield a consistent estimate. Thus, though the periodogram is only an unbiased estimate of the spectral density, the integrated periodogram is also a consistent estimate of the integrated spectrum. Generalising this Grenander [10] has considered the entire class of unbiased estimates which are the weighted sums of the periodogram ordinates in an interval which includes the frequency under consideration. The main object of such weighting is to select consistent estimates belonging to this class.

The process of averaging over an interval extending on either side of the frequency at which the spectral intensity is being estimated immediately leads to a new complication. We cannot now collect up the periodogram ordinates at the two ends of the spectral range. If the interval for averaging is to extend to h on either side of the frequency, the estimation fails over a range of length $2h$. This complication of the non-estimability of the spectral density at the ends is referred to by Grenander [17] as 'nonresolvability' of the spectrum by this method. The extent of this nonresolvability depends on the value of h . Besides this, we have the error due to the nonvanishing of the variance of the spectral estimate for any particular λ . It is found that the product of these two errors has a positive lower bound. Therefore we are led on to an uncertainty relation that after a certain stage, precision in one direction can be secured only at the expense of the precision

in the other. In the above work the process is specified to have an absolutely continuous spectrum. This specification is too restrictive and needs to be enlarged to include processes whose spectra contain the saltus part as well. If we are searching for hidden periodicities, the removal of this restriction is the first step if one wants to employ the tool of spectral analysis. It appears [18] that Grenander's form of weighted estimate may still be established to be a consistent estimate of the spectral density under the relaxed conditions at such points where it is meaningful to talk of such a density. This result leads us to a new and positive line of approach to the classical problem of the search for hidden periodicities in a trend-eliminated stationary time series.

(e) *Estimation of Economic Parameters :*

In recent years the number of studies bearing on statistical inference in economic time series has been steadily increasing. Beveridge wheat price series is one of the rare instances where an economic time series has been constructed over a very long period closing in the gaps by suitable extraneous considerations. A study of this series from the standpoint of stochastic processes has already been made by some of the workers. Barring such solitary instances, any study of economic phenomena has to invariably deal with short series and a number of series at the same time. The simultaneous study of such series has given rise to a new class of problems. When one constructs a linear stochastic economic model, one cannot proceed straight-away to an estimation of the parameters by the method of least squares, because an equation of behaviour in the model frequently contains more than one internal (or dependent) variable and is hence not a regression equation. Further one has to ascertain whether the constants in an equation have determinate values. Econometricians call this the problem of identifiability. The condition for identifiability is unverifiable, as it requires a knowledge of the rank of a matrix which depends on the unknown values of the constants to be estimated. A necessary consequence of identifiability known as the condition for identification can however be verified. After ensuring identification one solves for the internal variables linearly in terms of the predetermined ones, estimates the constants in the new equations by the method of least squares, and returns by inverse transformation to estimates of the original equations in the model. In the simplest case of exact identification, the estimates of the constants in the finally obtained equations of the model are the same as the maximum-likelihood estimates, inference being restricted to suit the conditional nature of the distributions of the variates that appear in the equations of the model. The foregoing results relate to the case in which the only admissible a priori restrictions on the constants in the equations of the model are that some of them vanish.

A systematic account of this and related problems is found in the book of Tj. Koopmans: *Statistical Inference in Dynamic Economic Models*.

Generally one of the main objectives of an econometric study is the estimation of elasticities. Any elasticity has got to be estimated simultaneously from the equations of the model. T. Haavelmo [19] has indicated how differentiation with respect to an external variable has to be carried out for each estimated equation of the model separately, and how the partial derivatives of the internal variables with respect to this external one should first be solved out from the set of simultaneous linear equations, and then elasticities calculated.

10. TESTING OF HYPOTHESIS

Though we are frequently handicapped in adopting the maximum likelihood method of estimation in time series studies, the situation is better when we come to tests of hypotheses. Let us consider a simple hypothesis H_0 against another simple alternative H_1 . These two hypotheses completely specify in two alternative ways probability measures on the function space. Applying Lebesgue decomposition of an additive set function and the Radon-Nikodym theorem to the two probability measures (which we may refer to as the P_0 -measure and the P_1 -measure), we have following Grenander [10] a non-negative function $f(\mu)$ integrable over the function space with respect to the P_0 -measure, and a set H of zero P_0 -measure such that for every measurable set S of the function space

$$P_1(S) = \int f(\mu) dP_0(\mu) + P_1(H \cap S)$$

This function f corresponds to the familiar likelihood ratio in the classical Neyman-Pearson method of testing hypothesis. If g_0 and g_1 are the frequency functions of the n variates of the process at time instants $t_1, t_2, \dots, t_n$, respectively on the null and the alternative hypotheses, it is known that the limit of the ratio of g_1 to g_0 is f almost certainly with respect to p_0 -measure. The general problem of constructing the best test function for testing the mean value function by this method depends on the solution of a certain integral equation, the accomplishment of which is not always straightforward or certain.

In the case of a discrete real stationary process, P. Whittle [20] has considered the problem of testing a given hypothesis H_0 against H_1 . The hypotheses considered are of the form that the time series is generated by a given moving average process or by an auto-regression. In this study, the author assumes normality of the variables as a part of specification. The asymptotic distribution of the ratio of quadratic forms which are the logarithms of the likelihood of the sample on the null and alternative hypotheses has been derived to work out large sample tests.

11. There is a lot more of work on time series which has not been referred to, such as large sample tests of goodness of fit, etc., This is due to the fact, that, as I have mentioned in the beginning, it is not my object to present to you a comprehensive survey of time series analysis. If I have succeeded in my modest endeavour to place before you, in a suggestive way without much obscuring detail, the technical ideas relating to some of the current problems of inference in time series, my task has not been in vain.

Let me conclude by saying that the prospect for statistical research is very bright indeed, and that we can legitimately hope to reach very soon new heights in the adventure of exploration of scientific truth.

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SECTION OF PHYSICS

PRESIDENT : B. PETERS, Ph.D.

Presidential Address

THE PRIMARY COSMIC RADIATION

1. INTRODUCTION

Cosmic radiation was discovered nearly 50 years ago. Its effects were first observed as a small residual ionization in gases, which could not be attributed to natural radioactivity of the earth and of its atmosphere. From this modest beginning a branch of physical science has developed which has profoundly affected and in some cases even revolutionized other fields of physics and has exerted a great influence on the development of other sciences, in particular astrophysics and archeology. Increasingly important contributions of cosmic ray research to geophysics, oceanography, meteorology and to cosmology, possibly even to the biological sciences must be expected.

In order to understand why results obtained in the study of cosmic rays have reached so far afield and have affected so many different branches of knowledge, we must consider separately three different aspects of the phenomenon of cosmic radiation: The incident particles themselves, the dissipation of their enormous energy inside the atmosphere, and the radioactivity which cosmic radiation produces on the surface of the earth.

a) The outer atmosphere of the earth is continuously being bombarded from all sides by various forms of radiation and matter: Photons of greatly varying wave lengths, a stream of atomic nuclei of widely varying mass and energy, as well as aggregates of matter ranging in size from very fine particles of dust to that of large boulders. Our entire knowledge about the properties of the solar system and of the universe which surrounds us and of which we form an insignificant part, even our awareness of the very existence of this universe, is based on a study of some part of this radiation and matter which bombards us.

The study of the electromagnetic radiation in the visible part of the spectrum has by far the longest scientific history and is responsible for most

of our present knowledge of the distribution in space and the motion of luminous stellar bodies, on the temperature and pressure conditions which exist on their surfaces, on the chemical composition of their envelopes, on their rotations and on the magnetic fields which often surround them. It has also given us some information on the size, the density, the distribution and the motion of interstellar clouds of dust and gases.

The study of the incident particle radiation on the other hand is comparatively new. Yet it has already taught us that the interstellar medium not only consists of turbulent gases and dust, but that it also consists of atomic nuclei moving with relativistic and near relativistic velocities and that it contains magnetic fields. One finds that the energy density due to cosmic radiation, to magnetic fields and to the kinetic energy of interstellar matter are of the same order of magnitude. It is clear that these facts alone are of greatest importance for theories dealing with the development of stars and galaxies and is fundamental to all problems of cosmology. The details of the chemical composition of cosmic radiation, its density and velocity distribution, its variations in time and space, will have to be understood in terms of the present physical conditions of our universe and thereby serve as tools to explore these conditions. In this way cosmic ray physics has become a part of *astrophysics* and *cosmology*.

b) On impact with the atmosphere the particles of the cosmic radiation destroy nitrogen and oxygen nuclei which they encounter and decompose them into their constituent parts (protons, neutrons and aggregates of these particles); in addition a large part of their enormous kinetic energy is transformed into a variety of highly unstable particles which subsequently decay through complicated chain events back into stable forms of matter. It is clear that the appearance of these particles (which are called mesons and hyperons) in high energy collisions is closely linked with the properties of the colliding protons and neutrons and is relevant to explaining the force responsible for their aggregation into the nuclei of elements which we observe on the earth. The role which these unstable particles play in the structure of matter is not yet clear; almost all of them were first discovered in cosmic radiation and these discoveries provided the impetus for building the large accelerators which now are among the most valuable tools for the investigation of nuclear forces. Thus, cosmic ray physics is an important part of nuclear physics.

Also the study of the interactions of electromagnetic radiation with matter has been strongly influenced by investigation of cosmic ray phenomena. High energy photons capable of producing electron-positron pairs in the coulomb field of nuclei were first observed in the cosmic radiation where they form a part in the decay chain of some mesons. Similarly the

direct production of electron-positron pairs by collisions between electrically charged particles at very high energies was first observed in cosmic ray work.

Thus, the influence of cosmic radiation studies on the fields of *electromagnetism*, *nuclear physics* and the *physics of sub-nuclear particles* stems mostly from the fact that cosmic radiation may be considered as a convenient tool for bombarding ordinary matter with a great variety of very high energy projectiles.

c) The significance of cosmic ray work for archeology, geophysics, oceanography and meteorology rest on the fact that during the complicated processes of interaction between cosmic radiation and its progeny with the atmosphere and the surface of the earth, a number of radioactive nuclei are produced with greatly varying half lives. These half lives though often quite long, are much shorter than those of naturally occurring radioactive substances which have survived in measurable quantities on the earth and in meteorites since the creation of elements some 5 billion years ago. There are two ways in which these radioactive nuclei are produced by cosmic rays. They may be produced directly by the partial fragmentation of nuclei in the air, or they may be produced by the capture of cosmic ray produced neutrons after these neutrons have been slowed down.

The first group contains the recently discovered cosmic ray produced Be^7 (half life 53 days) which may be useful for studying the circulation of air masses between the stratosphere and lower atmospheric layers and may also give information on the vertical circulation of ocean water. Another collision product is tritium (half life 12.5 years), whose concentration in lake and well water reservoirs has been used to obtain information on the rate at which these reservoirs are fed by contemporary water from recent precipitations. Finally the long lived beryllium isotope Be^{10} (half life 2.7 million years) is produced : it has not yet been isolated but it promises to be useful for dating geological surface changes during the tertiary and particularly for determining the sedimentation rates on the floor of the oceans.

Among the radioactive isotopes produced by slow neutron capture the most important one is C^{14} (half life 5,600 years) which has been used primarily to determine the time at which various organic materials have ceased to participate in the exchange of CO_2 between the atmosphere and the biosphere. The time of death can, therefore, be measured from the C^{14} concentration in the remains of plants, animals or humans and this technique has proved of great value for archeological research. Cl^{36} is another radioactive nucleus (half life 400,000 years) which can be produced on the earth's surface by cosmic ray neutrons and may be useful for dating geological events of the past.

Thus, the importance of cosmic radiation to *meteorological, geophysical and archeological research* is based on its providing a steady source of tracer elements which are incorporated into materials on the surface of the earth.

Whether cosmic radiation is of importance to the *biological sciences* is not yet clear. Since all high energy radiation is capable of producing mutations, the continuous cosmic ray bombardment, particularly at high elevation, must have been responsible for some genetic changes. It may, however, not be of sufficient importance compared with other agencies of mutation to have influenced markedly the history of evolution.

2. OBSERVATIONS ON PRIMARY PARTICLES

It is clear from these introductory remarks that an exhaustive discussion of cosmic ray physics is not possible in a single lecture. I must restrict myself to a particular aspect and I shall confine myself to discussing the properties of the cosmic radiation before it enters into interaction with the earth's atmosphere. This must immediately be qualified because direct measurements on cosmic ray particles in interstellar space cannot yet be carried out. Our measurements are at present confined to the neighbourhood of the earth's surface and only to the extent that we can gauge the influence of these local conditions on the primary radiation can we extrapolate to its true properties in interstellar space. Most of our measurements are still carried out with balloon borne equipment which means that the particles have not only traversed the earth's magnetic field, but also 1-2% of the atmosphere, before they are observed. The influence of these facts on the composition and the energy spectrum is by no means small and is not yet understood in detail. There is, however, hope that we can gradually extend our observations to regions further removed from local influences. Observations in rockets, at present of too short duration for detailed work, practically eliminate corrections due to interactions of the radiation in the upper part of the atmosphere; the use of satellites may in the near future extend the periods of observation sufficiently to permit accurate measurements outside the atmosphere. However, even then we still have to contend with the effects produced by the magnetic field of the earth and the fields in the space which surrounds it, as well as with the so-called albedo effect, which is the re-emission of secondary cosmic ray particles from the atmosphere.

A limited number of observations have already been carried out by studying the effect of cosmic ray bombardment on the chemical composition and the crystal structure of meteorites. Here we have a detector which for most of its period of registration was removed from the influence of the

earth, but the effects of the radiation are still observed under conditions given by the particular distribution of fields and matter which characterizes the central part of our solar system.

Recently, it has been suggested that a direct relation can be established between radio noise and the interaction of energetic particles with interstellar fields and interstellar matter. If such a relation can be established, effects produced by cosmic ray particles in various parts of the galaxy may become observable and in this sense it seems conceivable that some day the direct study of cosmic radiation in interstellar space may become practical. In the meantime most of our knowledge derive from more nearly earthbound experiments and is subject to the uncertainties involved in taking into account local influences.

3. THE IDENTIFICATION OF PRIMARY PARTICLES

The earliest experiments which gave information on the nature of the particles which are incident on the atmosphere were carried out on the surface of the earth. A systematic variation of cosmic ray intensity with geomagnetic latitude was observed. The decrease with latitude had to be attributed to a screening effect of the earth's magnetic field and it was thereby established that the radiation is due to electrically charged particles. The study of particle trajectories in a dipole field like that surrounding the earth revealed that in order to reach the atmosphere at a given latitude and from a given direction, the magnetic rigidity, the ratio of momentum to electric charge P/eZ of a particle has to exceed a certain minimum value; if the particles have positive charge this minimum value is lower for particles incident from the west than for those incident from the east, and therefore, the flux from the western sky should be higher than from the eastern sky. If the particles carry negative charge the asymmetry should be reversed. A small asymmetry exists at ground level indicating preponderance of positive charges. However, only when the asymmetry measurements were carried out near the top of the atmosphere with balloon borne equipment, did the asymmetry become sufficiently strong to prove that within the error of measurement all primaries carry a positive charge. These experiments rule out negative electrons as primary particles, but not positive electrons or atomic nuclei. Now, it is known that high energy electrons, whether positive or negative, quickly multiply in traversing absorbers of high atomic number by the process of bremsstrahlung and the subsequent production of pairs by the photons emitted in the bremsstrahlung process. Experiments, however, show that most high energy particles at great altitude traverse lead absorbers without such multiplication and that, therefore, not more than about 1% of the incident particle flux can be due to electrons. The only known particles which are stable and positively charged and can,

therefore, exhibit the behaviour indicated by these experiments are atomic nuclei. Thus, it was established that cosmic radiation is due to high energy nuclei incident on the earth from outer space.

The specific ionization produced by the particles occurring at high altitude when they traverse nuclear emulsions, proportional counters, ionization chambers, scintillation crystals or cloud-chambers shows that most of them are singly charged; therefore, the majority of primary cosmic ray particles is identified as hydrogen nuclei. But tracks in emulsions and in cloud chambers (and less conclusively the pulse height in counters of various kinds) clearly reveal that some of the particles must carry higher charges and must, therefore, belong to nuclei of higher atomic numbers.

The task of identifying the various nuclear species, the magnitude of their flux and their energy distribution is a difficult one, because at the highest altitude accessible to balloons and, therefore, available for extensive observation, interactions of primary nuclei in the residual atmosphere have already complicated the picture enormously.

The radiation at an atmospheric depth corresponding to a pressure of $10\text{-}20\text{ g/cm}^2$ consists of :

- a) Primary protons which have not interacted with nuclei in the upper layer of the atmosphere. These have at a given latitude an energy in excess of the minimum energy of admission determined by the earth's magnetic field.
- b) Primary nuclei with atomic numbers between 2 and 26 which have not undergone nuclear collisions,
- c) Secondary protons, neutrons and α -particles produced in collisions of primaries with stationary nuclei in the upper atmosphere. These have in general considerably lower energies than the primary components.
- d) Protons, neutrons, α -particles and heavier fragments which arise from the particle disintegration of heavy nuclei in flight and which have per unit mass approximately the same energy as the parent particle.
- e) Mesons of various types produced in nuclear collisions and their decay products, in particular γ -rays from the almost instantaneous decay of neutral π -mesons and electrons from the decay of μ -mesons.

The contamination of the primary flux by secondary particles can be reduced but not completely eliminated by carrying the detecting apparatus to higher and higher altitudes. The secondaries mentioned under (c) and (e) have not only a downward component but also a component which moves upwards from the atmosphere, and if electrically charged will re-enter the

atmosphere after the trajectories have been bent back by the earth's field at large distances. Under these conditions the determination of the flux of truly primary nuclei at a given latitude presents serious difficulties which have not all been overcome as yet. Most of the picture has, however, been unravelled by now.

Multiply charged energetic nuclei can directly be identified as belonging to the primary radiation, because although fragments of charge $Z > 1$ are often emitted in the disintegration of stationary nuclei, these fragments have always very low energy and a correspondingly small range in absorbers. Nuclear emulsions have proved to be the most suitable detectors for identifying the charge of heavy primary particles. The ionization produced by these particles is proportional to the square of their charge and approximately inversely proportional to the square of their velocity. If the velocity is known to be close to that of light, ionization measurements by themselves determine the charge. Otherwise the variation of ionization with range or the range itself must be measured in addition to specific ionization and one thereby determines both charge and energy of the particle.

4. THE STATE OF IONIZATION OF THE INCIDENT PARTICLES

By the time a heavy ion has traversed a very small thickness of atmosphere, it will be completely stripped of orbital electrons and its charge will be equal to its atomic number. The question then arises whether for heavy cosmic ray particles this stripping took place already in interstellar space or whether the heavy particles carry with them some orbital electrons into the atmosphere. This question can be answered, because the minimum energy of arrival at a given latitude determined by the earth's magnetic field, depends on effective charge which the particle had in a region which lies far beyond the atmosphere. By comparing the energy derived from the smallest observed range in absorbers with the minimum energy of arrival for completely and partially stripped ions at a given latitude, it was possible to show that the primary particles, even those of the heaviest elements observed, have lost all orbital electrons before they come under the influence of the earth's magnetic field. This is of great importance for three reasons:

- a) By measuring the flux at different latitudes with correspondingly different geomagnetic cut-off energies ϵ one can determine the number of arriving particles whose energy per nucleon exceeds ϵ and, therefore, one obtains the energy distribution of particles from small energies up to about $\epsilon = 7 \text{ BeV/nucleon}$, the cut-off value at latitude $\lambda = 0^\circ$

- b) The fact that the cut-off energy corresponds to that calculated for completely stripped nuclei shows that the heavy primaries are not produced by the fragmentation of fast dust particles arriving in the upper layer of the atmosphere; such dust particles would have a very low charge to mass ratio and would not, therefore be influenced by the earth's magnetic field.
- c) If we assume that at least the heaviest ions have begun their acceleration when they were still only partly ionized, they must before arrival, have traversed at least $12\mu\text{g}/\text{cm}^2$, many times the amount of matter which exists between the chromosphere of the sun and the earth. They cannot, therefore, have been accelerated in the neighbourhood of the sun and travelled directly to the earth.

5. THE CHEMICAL COMPOSITION OF THE PRIMARY RADIATION AND ITS MODIFICATION BY NUCLEAR COLLISIONS

It is of great interest to determine the relative frequency of various nuclear species in the primary cosmic radiation, in order to compare their chemical composition with that of the rest of the universe as established from the analysis of the earth's crust and of meteorites, from the analysis of starlight and from the absorption lines produced in the interstellar gas traversed by starlight.

In order to make such a comparison and thereby gain information on the properties of the source of cosmic ray nuclei it is, however, necessary to make corrections for the complete or partial destruction which the particles may have suffered in the upper layer of the atmosphere as well as in the interstellar gas clouds. We can observe the mean free path for nuclear collisions of heavy primaries in emulsions and in other materials and thereby estimate the probability that the atomic number of the incident nucleus has been reduced by various amounts during the passage through the upper atmospheric layer. This permits us to extrapolate to the top of the atmosphere the flux of those nuclei whose abundance is large compared to that of their immediate neighbours in the atomic table. It does not, however, permit us to say with certainty whether a particular fairly rare nucleus actually occurs as a primary or whether it represents a fragment of a primary of higher charge.

On the basis of measurements available so far one can state with certainty that nuclei of hydrogen, helium, carbon, oxygen, magnesium, silicon and iron are represented. The abundance of nitrogen which lies between the strong peaks of carbon and oxygen is not yet well established. The similarity of the relative abundance of different nuclear species in cosmic

radiation and in the universe at large, is striking. The elements mentioned are also, in the same order of decreasing abundance, the most prominent elements in the universe. The strong peak in the neighbourhood of iron as well as the rarity of elements heavier than iron is faithfully reproduced. It must, however, be remarked that compared to hydrogen and helium, the elements of the carbon, nitrogen, oxygen (C, N, O) group and particularly the still heavier group is by a factor of order 5 or 10 more abundant in cosmic radiation.

The correspondance between the universal abundance and the abundance of various elements in cosmic radiation is by no means trivial, because, if in their passage through interstellar space the heavy nuclei had an appreciable chance of colliding with nuclei of the interstellar gas, the composition would be greatly modified. Fragmentation should result in a higher percentage of light compared to heavy nuclei. Particularly the hydrogen and helium fraction should have been increased by fragments from the break up of heavier elements.

The survival of the iron peak indicates that the composition has not suffered serious changes in interstellar space, because the mean free path for the disintegration of iron in a hydrogen gas is only about 2 g/cm^2 , and and if iron survives the passage through the interstellar matter, the lighter elements with longer mean free paths have a still better chance to escape destruction in nuclear collisions.

There exists, however, a more sensitive method for evaluating the frequency of interstellar collisions. The elements Li, Be, B, are in the universe rarer by a factor of order 10^5 than C, N, O, nuclei, presumably because of their low threshold for thermonuclear reactions. On the other hand they are copiously produced in collisions between C, N, O, and heavier nuclei with hydrogen. There is no apriori reason why the elements Li, Be, B, should be rare in cosmic radiation, but if they are rare, it proves that few of the heavier nuclei have collided in interstellar space. It has been shown that in the primary radiation the ratio $(\text{Li, Be, B})/(\text{C, N, O})$ is less than 0.1*. From this it follows that the average primary particle has traversed less than 0.75 g/cm^2 of interstellar gas. It also proves, if the explanation for the rarity of Li, Be, B, in the universe is correct, that the particles which have been accelerated to cosmic ray energies have at some time since the creation of elements been subjected to high enough temperatures and to sufficiently high pressures to cause destruction of Li, Be, B in thermonuclear processes.

his low ratio was obtained for primaries whose energy exceeds 3.5 BeV/nucleon . In the energy region below this value, experimental results are still contradictory.

This would indicate that at some time the material which we observe as cosmic radiation has belonged to a star.

6. PROPERTIES OF THE SOURCE REGION

We have seen, that the chemical composition of primary cosmic rays has not been appreciably modified during their passage through the interstellar space. Their composition shows that in the region where they are accelerated the abundance of elements is similar to that of the rest of the visible universe. In addition, the absence of light elements Li, Be, B, shows that the material has at some time been subjected to high temperatures and pressures. We cannot, however, be sure from this alone whether the particles were accelerated while they were still part of a stellar envelope or whether they were accelerated when they belonged to interstellar gases which at some previous time had been subjected to thermonuclear reactions. There are properties of the primary charge distribution which may help to answer this question:

We find in the cosmic radiation nuclei belonging to atoms with very different ionization potentials; they occur in about the same abundance ratios as the corresponding elements in the universe. In particular helium with an ionization potential above 24 ev. is not particularly rare compared to, for instance, magnesium whose ionization potential is less than 8 ev. This seems to indicate a very high temperature in the source region at the time of acceleration, higher than the temperature of most regions in interstellar space. The source must lie in a region where even helium is mostly ionized because only ionized atoms will initially enter into the acceleration process.

Another possible experiment to check whether the interstellar gas or the stellar envelopes furnish the cosmic ray particles consists in establishing whether calcium exists in appreciable quantity in the cosmic ray beam. From interstellar absorption lines one concludes that calcium is much rarer in the interstellar gas than in the universe as a whole, possibly because, as has been suggested, it is easily adsorbed onto dust grains. If the cosmic ray particles came from interstellar gas rather than from stellar envelopes, calcium should be absent (though in view of the presumably strong neighbouring potassium peak, this may be difficult to establish). Present indications are that cosmic rays originate in a highly ionized medium, presumably, therefore, in the neighbourhood of stellar surfaces.

Many points relevant to these problems remain to be answered. The presence or absence of deuterons and of He^3 in the primary radiation has not yet been investigated. Both types of nuclei (as well as tritium which

decays into He^3) should be copiously produced in interstellar collisions of heavy primaries if such collisions occur. Like Li, Be, B, these nuclei are rare in the universe, being quickly consumed in thermonuclear reactions. The presence or absence of neon nuclei may also give important information because ionized neon apparently does not occur in the sun and in many other stars.

7. THE ENERGY SPECTRUM OF PRIMARIES

The total intensity of the primary cosmic ray nuclei with atomic number greater than 1, can be measured fairly easily. Subtracting the flux of heavy primaries from the total number of penetrating particles observed at great altitude one obtains the flux of primary hydrogen nuclei together with the flux of the secondary (albedo) particles mentioned earlier. The albedo correction to the primary flux is perhaps 10-30% but not well known as yet.

I shall talk only briefly about the energy distribution of primary cosmic ray particles. Up to energies corresponding to the geomagnetic cut-off at the equator the energy spectrum can be derived from the latitude effect. (This applies to protons of energy below 15 BeV and heavy nuclei below 7 BeV/nucleon). At high latitudes part of the heavy component is cut off by atmospheric absorption, their range being insufficient to reach balloon-borne equipment. In this case measurements at rocket altitudes are necessary. It seems that primaries with energies as low as a few hundred MeV are often rare or absent. This may be due to the difficulty which these particles experience in penetrating turbulent magnetized gas clouds moving inside the solar system.

At very high energies the energy of a particle can be deduced either from the detailed character of its collision with a stationary nucleus or from the total number of electrons and γ -rays, which the primary and its progeny produced as they dissipated their energy in the atmosphere. It is generally assumed that nearly one third of the energy goes into the production of neutral π -mesons which by their decay into γ -rays give rise to the electron-photon cascade. This assumption has not yet been proven for primaries above 10^{12} ev. and may be in error. The part of the energy which appears in the electron-photon cascade indicates that primary particles exist whose energy cannot be much less than 10^{10} ev.

Cosmic ray energies comprise, therefore, the enormous interval from a few times 10^8 to a few times 10^{18} ev. The number of primaries $N(\epsilon)$ incident per m^2 , sec, and steradian whose energy exceeds ϵ BeV per nucleon decreases

smoothly with increasing energy and can be approximated by the empirical formula:

$$\left[\log_{10} \left(\frac{K(Z)}{N(\epsilon)} \right) \right]^{\frac{1}{2}} = 0.222 \log_{10}(\epsilon + 1.7) + 2.645$$

where $\log_{10} K(Z)$ has the value

10.73 for protons ($Z = 1$)

9.67 for α -particles ($Z = 2$)

8.37 for C, N, O, nuclei $6 \leq Z \leq 8$

7.95 for $Z \geq 9$.

At present the energy spectrum of protons and α -particles is known up to about 10^{12} ev/nucleon, that of the C, N, O, group up to 7×10^9 ev/nucleon and that of the heaviest nuclei ($Z \geq 9$) up to 5×10^{10} ev/nucleon. Above 10^{12} ev. the chemical composition of the radiation is not known and the energy spectrum (with a value of $\log_{10} K = 10.77$) refers to the total number of incident particles whose entire kinetic energy exceeds ϵ BeV.

8. THE TIME VARIATIONS OF COSMIC RADIATION

Accurate intensity measurements on cosmic radiation have been carried out only for the last 20 years. The most remarkable feature of these measurements is the constancy of the radiation from hour to hour, day to day, month to month, and year to year. With the exception of 4 or 5 short lived disturbances during these last 20 years the fluctuations on the ground rarely exceed 1%. The absence of a major diurnal variation shows not only that direct emission of particles from the sun to the earth is insignificant, but also that the radiation in the neighbourhood of the earth arrives in equal strength from all directions and must, therefore, be distributed isotropically in the neighbourhood of the earth.

There are small sudden world wide *decreases* of cosmic ray activity, always associated with solar flares: These disturbances begin usually 1-2 days after the onset of the flare and are followed by a recovery lasting several days. They seem to be associated with turbulent gases ejected from the surface of the sun. The so called 27 day variation which consists of small decreases in cosmic ray intensity with a tendency to recur in phase with the 27 day period of solar rotation, have presumably a similar origin. There also seems to exist a small variation with a period of 11 years corresponding to the periodicity in the occurrence frequency of sun spots.

In all the 20 years of observation there were only 4 or 5 large short lived *increases* of intensity. These were connected with exceptionally large

explosions on the solar surface, were not world wide but strongly dependent on local solar time and were confined to the low energy part of the spectrum, being unobservable at low geomagnetic latitude. These observations seem to indicate that direct emission from the sun occurs but contributes **very** little to cosmic radiation.

Apart from the types of variation listed here, there are only those which can be traced to pressure and temperature changes in the atmosphere and are, therefore, not connected with true variations in the primary intensity.

Periodic variations with the period of a sidereal day which would indicate anisotropy of primary particles in space have been searched for, but not been established definitely; if they exist they are not larger than about 0.1%.

As far as long time intensity variations are concerned, the concentration of the cosmic ray produced C^{14} isotope in materials of various ages, shows that the primary radiation has stayed essentially constant for at least 30,000 years.

9. THE PROPAGATION OF COSMIC RAYS IN INTERSTELLAR SPACE AND THE SHAPE OF THE GALAXY

The isotropy of the incident radiation makes it very unlikely that the sun is mainly responsible for the cosmic ray particles observed by us, in spite of the fact that the sun seems to emit occasionally, in connection with its flare activity, particles of energy up to 5×10^9 ev. or somewhat higher. Even if we assume that in rare major outbursts particles of much higher energy can be emitted, it seems impossible to construct a magnetic field of sufficient strength and of such special shape as to render the distribution of particles with energies up to 10^{15} ev. or higher, isotropic in the neighbourhood of the earth. We are forced to place the origin outside of the solar system.

Our galaxy has generally been considered to be an elliptically shaped disc whose thickness of about 1,000 light years is less than one tenth of its minor axis; the solar system is placed fairly far towards the rim of the disc and somewhat off the median plane. The distribution of visible objects which could serve as sources of cosmic radiation, like stars, planetary nebulae and clouds of interstellar matter are distributed very unevenly in this disc being strongly concentrated in the center of the galaxy. Unless the cosmic ray sources are numerous invisible objects like low luminosity stars uniformly placed around the earth at a distance small compared to the thickness of the galaxy, the observed isotropy of radiation must be due to frequent large angle deflections in the trajectory of cosmic ray particles and

possible reflections at the galactic boundary. Large deflections without destruction of heavy nuclei can only be produced by large scale electromagnetic fields and since the very high conductivity of interstellar matter prevents the establishment of electric fields, the isotropy of cosmic rays implies the existence of irregular magnetic fields in interstellar space. The existence of such fields of magnitude of 10^{-5} to 10^{-6} gauss can be derived theoretically from the properties of the highly conducting turbulent gas and dust clouds which are found to exist in interstellar space; it has also found experimental support in the observation of the partial polarization of starlight traversing such clouds. The isotropy of cosmic rays is, therefore, due to their travelling in extremely tortuous paths resulting in a kind of diffusion by frequent changes of direction when passing through regions of varying magnetic fields.

Particles originating near the center of the galactic disc can obtain an isotropic distribution near the rim of the disc, where we are located, only after suffering very many large angle deflections, which means after travelling a very long path. They must traverse along this path very much more interstellar material than the upper permissible limit of 0.75 g/cm^2 which we have deduced previously from the chemical composition of the primary radiation, in particular from the absence of fragmentation products which must arise from nuclear collisions in interstellar space. Stellar objects most likely to act as accelerators of high energy particles, are strongly concentrated in the galactic plane near the center of the galaxy. If we must discard these possible emitters of high energy particles, because they are too far away from us, we must look for possible sources within about 1,000 light years from the solar system, where few, if any, suitable stellar objects seem to be located.

The solution of this difficulty lies apparently in the fact that cosmic ray particles are *not* confined to move in the flat disc which contains most of the galactic matter. Magnetic fields which inhibit their escape, extend much farther into space than has hitherto been assumed. Recent studies of galactic radio noise in our own galaxy and particularly in the neighbouring galaxy Andromeda indicate that the emission of radio noise also is not confined to the galactic disc but occupies a much larger volume which is nearly spherical in shape. It seems, that while the gas density at large distances from the galactic plane is much lower than in the disc, the gas velocity is higher, such that the kinetic energy density and the magnetic field density, which is closely dependent on it, decrease only slowly in the direction perpendicular to the galactic plane. In this approximately spherical volume in which the average density of gas atoms is much lower than in the disc itself, cosmic radiation originating in the galactic center or

in any other part of the volume can, by diffusing within the turbulent magnetic field regions, obtain a high degree of isotropy without traversing an amount of matter large enough to disintegrate the heavy nuclei which it contains.

10. ON THE ORIGIN OF COSMIC RAYS

Various theories have been proposed as to how particles could be accelerated in the galaxy to very high energies. Magnetic variable stars, and stars whose magnetic axis does not coincide with their axis of rotation have been investigated in some detail as possible accelerators. The conversion of the kinetic energy of interstellar gas clouds into cosmic ray energy has also been considered. There are serious objections to these proposals. Nevertheless it is possible that they play a role in the production of cosmic rays.

However, one celestial object has been discovered which *does* accelerate particles to cosmic ray energies, although we do not understand how it accomplishes the acceleration. The object is the so-called Crab Nebula, a rapidly expanding luminous gas cloud resulting from the explosion of a supernova, which according to Chinese sources occurred about 900 years ago. The light emitted from this cloud is largely and perhaps entirely polarized. It can, therefore, not arise from atomic or molecular excitations but must be due to the radiation of electrons spiralling in a magnetic field. From the intensity and spectral distribution of the light and the ratio of light to radio noise the energy distribution and density of the electrons and the strength of the magnetic field can be estimated. The energy distribution may be similar to that of cosmic ray particles. Most of the visible light seems to be due to electrons of energy 2×10^{11} ev. spiralling around a field of order 10^{-3} gauss. The radiation loss of these electrons is so high that their average life as fast particles can only be of the order of 60 years. They must, therefore, continuously be replenished from the center of the nebula. The same mechanism must also accelerate positive ions to comparable energies, which then will circulate around the same field lines in opposite direction. The ions, however, because of their large mass, radiate only a negligible fraction of their energy and once accelerated remain high energy particles. The total energy which is converted in the Crab Nebula into kinetic energy of particles is of a magnitude which is perhaps sufficient to account for the total observed cosmic ray intensity, if one assumes that (as indicated by observations on other galaxies) our galaxy produces on the average one supernova every 200 or 300 years.

It is not clear as yet, whether the observations on the Crab Nebula are consistent with its emitting cosmic ray particles of energies as high as 10^{19} ev.

or whether we have to look for other mechanisms in this ultra high energy region. The detailed mechanism of acceleration and the origin of the enormously high magnetic field energy appearing in this supernova explosion are also as yet quite unknown. Nevertheless the existing evidence gives strong support to the hypothesis that supernovae and perhaps novae are sources of cosmic radiation.

SECTION OF CHEMISTRY

*President :—*DR. S. HUSAIN ZAHEER, M.A. (Oxon.),
Dr.Phil.Nat. (Heidelberg),

PRESIDENTIAL ADDRESS

THE PROBLEM OF DOMESTIC FUEL AND ITS SOLUTION THROUGH LOW TEMPERATURE CARBONISATION

1 The level and pattern of utilisation of energy in any country is an indication of the country's social and material development. The annual per capita energy consumption in industrially-advanced countries is estimated to be of the order of 2400 therms, while in under-developed countries it is estimated to be 100 therms. In India, the annual per capita consumption of energy is estimated at 80—100 therms or a total applied heating value for the whole country of only 3566×10^{12} B.T.U.¹, which means that it is a severely under-developed country. It is expected that during the next 10 years we will reach a total of 5000×10^{12} B.T.U which is an extremely modest target.

1.1 It is important to remember that not only the total quantity of energy consumption, but also the extent to which the pattern of energy development is rationalised, is directly related to the level of industrial development of a country. All the world over, industrially backward countries rely for sources of fuel mainly on 'waste products' (firewood, charcoal and farm waste) as against 'fossil fuels.' For India the following pattern of annual energy source distribution has been computed after a number of adjustments and approximations :—

TABLE 1.

Source	Approximate heating value in B.T.U.	% of total heating value	Coal Equivalent in Million Tons
1. Farm waste	2000×10^{12}	56.0	77.2
2. Fuel wood (35 million tons)	500×10^{12}	14.0	19.5
3. Coal (35 million tons) ...	900×10^{12}	25.3	35.0
4. Oil (3.6 million tons) ...	140×10^{12}	3.9	5.4
5. Hydropower (approx. 2×10^6 KWH) ...	26×10^{12}	0.8	1.0
Total ...	3566×10^{12}	100.0	138.1

1.2 Approximate calculations indicate that of the total 77.2 million tons coal-equivalent farm waste, about 45.5 million tons coal-equivalent is being burnt as fuel, the rest being used at present as manure. Out of the

45.5 million tons coal-equivalent, about 40 million tons account for equivalent cow-dung cake and the rest for miscellaneous forms of farm waste. In actual weight, this works out to about 80 million tons cow-dung cake. This quantity of cow-dung cake, if used instead for manurial purposes, would release about 480,000 tons of nitrogen per year but would require an additional 40 million tons of coal to be utilised for domestic purposes.

1.3 The above table shows that annually about 35 million tons of wood are used as fuel. Forest statistics² indicate that only about 10 million annual tons are being cut down from forests for fuel purposes. The remaining is accounted for by the large quantity of wood procured from 'non-forest' areas such as private lands, waste lands, etc., and unauthorised and indiscriminate tree felling about which no statistical data are available. This does not take into account the terrific drain of vegetation brought about by excessive and unscientific grazing and the depredation of goats and unproductive cattle.

1.4 With a steadily growing population, the rate of deforestation is increasing alarmingly and there is a large gap between afforestation and deforestation. It appears quite impossible to fill this gap through our present measures of afforestation unless there is a change-over in the pattern of fuel utilisation. This is even more alarming when we realise that existing data³ estimate the area covered by forests in India at 15% of the total geographical area of the country as against the minimum of 30% required to maintain proper rainfall and soil conservation. The devastating consequences of indiscriminate deforestation and inadequate afforestation, such as severe soil erosion, extensive floods and irregular weather conditions are now too well known to need elaboration here.

1.5 It might also be noted that in India the per capita consumption of wood as fuel and for industrial purposes is in the proportion of 1 : 1 as against 1 : 5 in U.S.A. and 1 : 3 in Germany.⁴

1.6 It is therefore necessary to cut down the use of fuel wood and farm waste as domestic fuel and one of the major problems confronting fuel technologists in India is to provide a suitable substitute or substitutes based on fossil fuels. For the moment I shall overlook direct solar energy as an alternative and since at present our known sources of mineral oil and natural gas are inadequate, we shall have to largely depend on our abundantly occurring indigenous raw material coal as the source material.

1.7 In a large country like ours with a predominantly agricultural population and with severe limitations of transport facilities, it may not be possible to bring about a complete change-over of the fuel habits of the people, and it is likely that the population in the country will continue to use fuel wood and charcoal as well as farm waste. The change-over can however, be brought about, perhaps gradually, but only when attractive and cheap alternative fuels are made available. Today there is hardly any alternative and until such alternative is provided, we shall continue to live in the 'cow-dung age'.

2 Having now put before you the problem and its solution as I see it, I propose, in this address to touch briefly on the possibilities of low temperature carbonisation (L.T.C.) of coal to supply alternative fuel for domestic use. Before, however, I go over to the details of the production of domestic fuel by L.T.C., I would like briefly to touch upon a few important aspects of this problem.

2.1 I have mentioned earlier that it is important to increase not only the quantum of energy consumption but to rationalise the pattern of energy production and utilisation. Table 1 shows the present pattern of energy production in our country to be 70% from fuel wood and farm waste, 25%

from coal, 4% from oil and 1% from hydro-electric power. Lahiri's studies⁵ on the future possibilities of energy utilisation with a total energy consumption of 5000×10^{12} B.T.U. indicate that the pattern of energy production can be changed to 50–60% from coal, 8–10% from oil, 30–35% from wood and farm waste and the rest from hydro-power. When this pattern is correlated with the likely energy requirements by about 1970 and then distributed among different spheres of energy utilisation, then as estimated by Lahiri,⁶ the domestic and transport requirements of the country consume nearly 65% of the total energy production from all sources. This includes about 130×10^6 tons of fuel wood and farm waste (equivalent to about 65×10^6 tons of coal) to be used as domestic fuel; and coal, semi-coke, kerosene, diesel and motor fuels, equivalent to about 78×10^6 tons coal equivalent to be used for domestic and transport requirements.

2.2 If, therefore, we set before us, with Lahiri,⁶ the comparatively modest and feasible task of the production of about 20 million tons of L.T.C. coke in order to (1) stop any increase during the next ten years in the use of farm waste and firewood as domestic fuel, (2) to meet all the increased requirement for domestic fuel with the increase in our population and the expected increase in our standard of living, and (3) to replace at least a part of the firewood and farm waste being used today as domestic fuel, we shall be doing something which in my view is perfectly feasible and attainable, and will directly and indirectly lead to an almost revolutionary change for the better in our social and economic life and our domestic and agricultural habits and practices. I have no doubt in my mind that unless we bring about this change-over, it will be quite impossible to put 30 per cent of our land under forests and to prevent the devastating effects of soil erosion due to deforestation and the impoverishment of the soil due to lack of requisite manure because of use of farm waste as fuel. I have also no doubt that it is this change-over brought about during the last 100 years in some of the Western countries from the use of the so called "waste products" (firewood and farm waste) to "fossil fuels" both in the industrial and domestic fields which is to a large extent responsible for the "changed look" of these countries—more grass lands and forests, little signs of soil erosion, greater fertility of soil and greater cleanliness.

2.3 The competitors for domestic fuel are of course electricity, oil, gas and semi-coke. Not having, at least not yet known, supplies of appreciable quantities of natural mineral oil and gas, we have to depend for all the above forms of fuel chiefly on our non-caking or weakly caking coals—unsuitable for metallurgical purposes and of which enormous quantities are known to exist and are available in our country.

2.4 For the production and preparation of 20 million tons of semi-coke, we shall require to handle about 40 million tons of coal—about half of which will be available in the form of smalls and fines. The only possible and rational utilisation of 20 million tons of coal fines and smalls would be for thermal power generation using pulverised fuel boilers and gasification to produce synthesis gas and fuel gas. From the carbonisation plants also we shall have available considerable quantities motor spirit, diesel oil, fuel oil besides tar, pitch and gas depending upon the nature of coals carbonised and the process used.

2.5 Thus we see that in addition to the 20 million tons of semi-coke, we shall have large quantities of gas and oil besides electricity available as domestic fuel and for our transport industry. In a series of admirable articles in recent issues of F.R.I. News,^{1, 5, 6} Lahiri has pointed how all

this is to be integrated and developed simultaneously, and I wish to further emphasise two points mentioned by him.

2.5.1 Firstly, if we are to bring about the contemplated industrial development, our railways and transport system must change over from coal to electricity and diesel locomotion. When it is remembered that about 1 million tons of diesel oil can replace about 10 million tons of coal for railways, the advantages become obvious without requiring any further elaboration. Anyone can see that on the basis of logistics only dependence on the old form of coal locomotion will lead to a complete breakdown in our railways, and consequently in our transport system and block our industrial development. It would therefore, be advisable for the railways to expand in the direction of diesel and power traction. In addition to facilitating better transport, this would save large quantities of coal. The supply of diesel oil and electric power for transportation can be conveniently integrated with L.T.C. industry, and the coal screening and washing plants.

2.5.2. Secondly, an important source of domestic fuel supply is coal gas and it seems to me that insufficient attention is being paid in our country to this important source. All industrially-advanced countries use gas for their industrial as well as domestic requirements. Wherever possible in India, attempts should be made to introduce along with electricity gas supply for domestic use. Undoubtedly there are many technical problems involved in the supply of gas among Indian public. These however, are not insurmountable and can be solved provided a planned effort is made. It would seem to me that we should resort to long-distance transmission of fuel gas produced from plants located in coal-producing areas, in view of the fact that railway transport of solid fuel over long distances is wasteful and should be reduced to the minimum. Solid fuel and gaseous fuel are complementary and a balance can be struck between these two from the viewpoint of distance and distribution to different cities and townships. Any fuel plan for the future should therefore provide for simultaneous expansion of gas supply and semi-coke manufacture. A rough estimate indicates that there is scope for the use of about 10 million tons of coal only for the production of fuel gas to Indian cities and townships within the next 10 years, besides the large quantities of surplus gas which may be available from coke ovens and refineries.

2.6 I shall now deal with some of the general considerations as well as the important details of the processes available for low temperature carbonisation.

3. *General considerations*: From the point of view of conservation and proper utilisation of Indian coals, L.T.C. should be based only on weakly caking and non-caking coals and high ash caking slacks, reserving the caking coals for metallurgical purposes. The estimated reserves of Indian coals and the zonal distribution within the country are presented in Table 2.

3.1 It can be seen that the coal reserves in India offer good possibilities of developing large scale L.T.C. and tar distillation industries. The capacities of the plants to be established and their distribution are however, important factors and will depend upon the estimated present demand in particular zones for domestic coke. Several proposals are reported to have been made by various State Governments for establishing L.T.C. plants in different coal fields to produce semi-coke. The estimated production potentialities of these plants are given in Table 3.

3.2 It will be seen that the production of semi-coke from the proposed plants is far short of the estimated demand. With proper organisation of

transport facilities it should be possible to expand semi-coke supply to all the towns and cities and this would necessitate installation of a greater number of plants. The manufacture of semi-coke in the plants already contemplated would also result in the production of about 360,000 tons of

TABLE 2.

Coal Reserves in India

I. Reserves with 20% ash and lying within 1000' depth and in seams of thickness 4' and more (in million tons)

1. Darjeeling foot hills, Lisu Ramthi area ...	...	...	20
2. Giridih, Jaintia and Rajmahal Hills ...	...	...	80
3. Raniganj, Jharia, Bokaro and Karanpura ...	...	...	10,150
4. Son Valley—Hutar to Umania and Sohagpur ...	...	...	2,000
5. Chhatisgarh and Mahanadi (Talchir) ...	...	...	1,200
6. Satpura Region in Mohpani to Kanhan and Penchi ...	...	...	150
7. Wardha-Godavari to beyond Singareni ...	...	...	6,400
			20,000

II. Tertiary Coals (in million tons)

1. Coalfield of upper Assam, Makum, Janpur Nazira ...	...	...	1,000
2. Coalfields of Garo, Jaintia and Khasi Hills ...	...	...	1,000
3. Bikaner ...	...	...	10
4. Jammu and Kashmir ...	...	...	27
5. South Arcot Lignites ...	...	...	2,000
			4,037

III. Reserve with 16% ash (dry basis) and lying within 2000' (in million tons).

				All Coals	Coking Coals
1. Giridih and Jaintia ...	...	...	...	22	20
2. Raniganj ...	...	...	...	1,763	230
3. Jharia ...	...	...	...	1,210	860
4. Bokaro ...	...	...	...	795	315
5. Karanpura ...	...	...	...	750	—
6. Hutar Johilla ...	...	...	...	50	—
7. Kurasia, Jhilmili etc. ...	...	...	...	27	—
8. Mohpani, Kanhan ...	...	...	...	30	—
9. Talchir and Korba ...	...	...	...	198	—
10. Ballarpur, Singareni ...	...	...	...	45	—
				4,890	1,425

TABLE 3.

Coalfield area	Plant Capacity (annual tons coal) millions	Expected yields (Annual tons)		Estimated present demand for semi-coke (Annual tons) millions
		Semi-coke millions	Tar millions	
1. Bengal-Bihar ...	2.7	2.0	0.25	2
2. Madhya Pradesh ...	0.5	0.34	0.04	1
3. Hyderabad ...	0.27	0.18	0.016	1
				(Hyderabad and Andhra)
4. Neyveli (Lignite)	0.714 (lignite briquettes)	0.38 (lignite char)	0.0513	1 (Madras and South)
Total ...	4.184	2.90	0.3573	5

low temperature tar which can be processed to yield diesel oil, motor spirit, important chemicals and other products as desired.

3.3 It is understood that proposals have been made also for development of Assam coals; details are however, not available. Rajasthan and Kashmir lignites can also be developed in a similar manner although I am not aware of any concrete proposals made so far to that effect.

4. *Plants and Processes*: More than 250 different processes are reported to have been developed for L.T.C. of a variety of materials such as bituminous coals, brown coal, lignite, peat, shale, etc. Most of these processes have not survived the test of economic commercial feasibility. All the processes were developed with the same common aim, namely, to produce uniform and non-friable lump 'coke' for use as domestic fuel with maximum ease and economy of operation. No process of L.T.C. could however be applicable to all raw materials to produce maximum yields of all products. The L.T.C. processes developed so far can be broadly classified into (a) externally-heated and (b) internally-heated systems. Each system can be further subdivided depending on whether (i) the retort is horizontal, vertical or inclined, and (ii) the charge is stationary or moving. These can again be classified on the basis of operational details, materials of construction, etc.

5. Here, it is not possible nor necessary to cover the various types of plants on which extensive literature is available. It is intended here to discuss only the more important processes which are well-established by now and are in commercial operation as well as those which show such promise. They are (i) Disco (U.S.A.), (ii) Coalite (U.K.), (iii) Krupp-Lurgi (Germany), (iv) Brennstoff-Technik (Germany), (v) Fuel Research Board (U.K.), (vi) Koppers (Germany), (vii) Rexco (U.K.) and (viii) Lurgi-Spielgas (Germany).

5.1 *Disco Plant*: The Disco Plant,^{7, 8, 9, 10} developed in the U.S.A., is based on the Wisner system. This has a rotary carbonisation retort and a pretreatment chamber arranged with a slightly downward incline. The pretreatment chamber consists of cast iron plates arranged in a zig-zag manner and heated from below. The carbonisation retort consists of a sheet steel cylinder surrounded by a second steel cylinder to provide an annular space through which hot combustion gases from a separate combustion chamber can pass. The interior of the carboniser is divided into 3 zones by 'ring dams.'

5.1.1 Feed coal mixed with recirculated coke breeze is roasted in the pretreatment chamber and passes successively through the softening, plastic and carbonising zones of the carboniser. In the plastic zone, the plastic mass is shaped into balls by the rotating action of the retort. The carbonisation time is governed by the ring dams and lifters built into the walls of the carboniser.

5.1.2 Normally the plant utilises weakly caking coals. The process can be successfully adapted to caking coals by partial oxidation in the pretreatment stage to reduce their agglutinating properties. Non-caking coals cannot be carbonised satisfactorily by this system. Further, only slacks can be treated satisfactorily; lump coals tend to produce excess fines, particularly non-caking coal, contaminating the tar. The process is continuous and fairly high throughput rates can be maintained. The Disco plant located at Pittsburgh has a capacity of 1050 tons/day and has been in operation since 1949. A smaller plant was however, operated since 1933. The rotary carbonising retort at the Pittsburgh plant is 9' in diameter and 126' long and each retort has an average throughput of 150 tons dry coal/day. The general operational data on the processes are presented in Table 4.

TABLE 4.

General Operational Data of different L.T.C. Processes

Process.	Disco.	Coalite	Krupp-Lurgi*	B.T.*	Narrow Brick Retorts (Fuel Research Board)	Koppers	Rexco.	Lurgi Spuelgas
1. Material of the carboniser wall.	Cast Iron	Special Cast Iron	Steel.	Steel	Fire Brick.	Fire brick.	Fire brick.	Fire brick.
2. Type of coal used.	Caking and weakly caking bituminous coal.	Non-swelling caking slack.	Weakly caking.	High Volatile weakly caking.	Weakly caking or caking.	High Volatile weakly caking.	Noncaking.	Noncaking and weakly caking.
3. Size of coal.	$\frac{3}{8}$ "	$\frac{3}{4}$ "-1/10" (usually 15%, $\frac{1}{2}$ "-1" and 88% $\frac{1}{2}$ ".)	0-10 mm.; 9% feed is fine coke; 70% $\frac{1}{2}$ mm.	Nut or fine.	Slacks (45% $\frac{1}{4}$ ")	>1 " 65% 1-3/8", 25% $<3/8$ ", 10%	4"-2 1/2" 2 1/2"-1" in the ratio 2:1	1/2" minimum.
4. Continuous or Batch.	Continuous.	Batch.	Batch.	Batch.	Continuous.	Continuous.	Batch.	Continuous
5. Temperature of carbonisation.	450-480°C (coal pretreated at 320°C).	625-630°C in radiation space; 500-510°C in centre of charge.	Gas temp. 630°C, oven temp. 610°C.	Not exceeding 600-610°C.	600-700°C; (flue gas temp. at top: 1100-1200°C; at bottom: 700-800°C)	Usually 700°C Max. 800°C.	Below 700°C.	600-650°C.
6. Time of carbonisation.	—	4 hrs.	4 hrs.	2 hrs.	—	21 hrs.	8 hrs.	5 hrs.
7. Yield per ton of coal								
Coke, cwt.	14.2	14	15	15	14.4	12.8	13.4	13.3
Tar, gal.	14.75	18	20-21	19.7	15.2	24	20.3	25
Gas, cft.	3640	4000-4500	3200	4550	6455	11,300	21,400	4230
C.V. of gas (BTU/cft.)	415	800-850	830	680-730	654	470	140	198
8. Volatile Matter in coke.	17.0%	9-10%	9%	18% (as discharged from carboniser).	—	5-6%	—	8-10%
9. Heat requirements in BTU to carbonise 1 lb. of coal.	612	—	900-1000	1080	885	990	—	—

* Data collected by Dr. S. Husain Zaheer and Dr. M. G. Krishna during their visit to the plants at the invitation of the Government of the Federal Republic of Germany.

5.2 *'Coalite' plant*: The *'Coalite'* plant at Bolsover in U.K.^{11, 12} uses metal-walled retorts each consisting of a monobloc casting of special cast iron. Each retort contains 12 tubes tapering upwards, 9' high and $5\frac{3}{4}$ " diameter at bottom and $4\frac{1}{2}$ " diameter at top. The taper is provided to facilitate coke discharge. Several retorts are grouped with combustion chambers to form a battery. The retorts and combustion chambers are arranged alternately, so that each retort is located in a radiation chamber formed by the brickwalls of two adjoining combustion chambers. The retort walls are therefore heated only by radiation and they do not come into contact with flames. Each pair of retorts discharges the coke into a common cooling chamber where the coke is cooled for about 4 hours. Each retort can carbonise 11 cwts. of coal and carbonisation is completed in 4 hours.

5.2.1 The plant at Bolsover has been in operation since 1936 and has 13 batteries of 40 retorts each, with a total coal throughput of more than 300,000 tons per annum. Normally non-swelling caking slacks from washeries are used, together with weakly caking or non-caking slacks up to 12 per cent. The plant is unsuitable for lump coals and non-caking coals. The design of the retorts limits the throughput rates. Each retort normally lasts only for 5-6 years. The yields and general operational data are given in Table 4. The yields of coke and tar are high and the products are of good quality. Due to the stationary character of the charge in the retort, the tar is not contaminated with any dust.

5.3 *Krupp-Lurgi plant*: The Krupp-Lurgi process¹³ developed in Germany before the second world war also has retorts with metal walls. During the war two plants, one at Wanne-Eickel and another at Velsen, were in operation. At present only the Velsen plant is working. The information presented here is based on the studies made during my visit to Velsen.

5.3.1. The plant at Velsen consists of 32 retorts. Each retort has six cells, holding 2.4 tons charge. Each cell is 3.15 m. long, 2.3 m. high and about 75 mm. wide at the top and 100 mm. wide at the bottom. The increased width at the bottom facilitates easy discharge. The cells are interposed with heating flues through which heating gases from a separate combustion chamber are circulated. The cell walls are made of 23 mm. thick boiler steel plate. Each retort is provided with a top cover and a metal grid at the bottom to close the cells. The grid contains metal slabs alternating with slots. During carbonisation, the slabs close the cells tightly. At the discharge time, the grid is drawn sideways so as to bring the slots in position below the carboniser cells. The Velsen plant has a capacity of about 400 tons coal/day and is stated to be in operation for about 15 years. The carboniser cells have a life of more than 10 years.

5.3.2 The general operational data on the Velsen plant are presented in Table 4. The process is suitable for weakly-caking coals. Lump coals and caking coals cannot be treated in this plant. There is no special cooling arrangement for the coke. The plant gives satisfactory coke and tar in good quantities. The operation of the plant is quite simple. It is however, not clear how satisfactorily the discharge mechanism operates without causing breakdowns. It is quite an elaborate mechanism and needs careful maintenance in order to keep it leak-proof and trouble free.

5.4 *Brennstoff-Technik Process*¹⁴: The B-T process using narrow metal-walled chambers was developed during the last war in Germany as a result of researches intended to devise a suitable plant and process to treat all types of coals and to produce 'true low temperature tar.' In this process

high speeds of carbonisation are maintained at a uniform and accurately controlled temperature to check cracking of primary tar.

5.4.1 A plant based on this process was erected by Dr. C. Otto and Co., Bochum during the war at Marienau and is now operated by the Les Houillères du Bassin de Lorraine. The plant having a capacity of 100 tons/day has one oven consisting of 12 cells which can hold 10 tons per charge. Each cell is 90 mm. wide, 2860 mm. long and 5400 mm. high. The walls of the cells are parallel. In order to facilitate discharge of the coked mass, one of the walls is hinged at the top so that the bottom part can be swung aside by 250 mm. Heating flues are arranged between the carbonising cells. The movement of heating gases is specially directed so as to maintain efficient and uniform heating conditions. In the Marienau plant, the coke with 18 per cent volatile matter falls into a secondary heating chamber arranged below the carboniser. In the secondary chamber the coke is heated directly to 900°C . by the hot products of combustion obtained by burning the secondary gas and by recirculating the mixed gases. The excess gas from the secondary chamber has a C.V. of about 100-120 BTU/c.ft. The secondary chamber can hold twice the charge capacity of the 12 carboniser cells and thereby the coke is cooled to about 40°C . by the time it leaves the secondary chamber. The general operational data on the plant are presented in Table 4.

5.4.2 The Marienau plant is processing ovoid briquettes with about 40-42 per cent V.M. and 6 per cent ash. It is claimed that the B.T. plant can treat any type of coal of a wide range of sizes. Hansen¹⁵ claims that it can carbonise fine and lump coals of any caking capacity and that the width of the cells may be varied depending on the caking capacity of the coal. Obviously, there are practical limitations to this claim ; for instance, bigger size coals cannot be carbonised satisfactorily with high carbonisation speeds in wide ovens when they are externally heated. This is particularly true when non-caking coals have to be treated. Thau¹⁶ remarks that the B.T. process cannot treat non-caking coals in lump form. The process however appears on theoretical grounds satisfactory for caking and weakly caking coals. On the basis of my personal observation at Marienau, it was not clear how reliable the swinging walls can be over long period of operation, in view of the generally accepted principle that internal moving parts should be avoided in ovens of this type.

5.5 *Narrow Brick Retorts*¹⁷: The Fuel Research Station in U.K. has developed vertical narrow brick retorts with a continuously moving charge. Plants of this type are in operation in U.K. at the South Yorkshire Chemical Works Ltd., Parkgate.

5.5.1 The retorts, built of firebricks, are 21' 9" high, 6' 6" long and 11" wide at bottom, tapering to 7" width at top. Coke is continuously discharged at the bottom of the retort into a coke chamber where it is cooled with steam. Heating of the retorts is effected by hot combustion gases flowing externally in a zig-zag path in horizontal flues. The heating gases enter the flues at the top at maximum temperature and flow downwards. Fresh coal is thus subjected to high heating rates and the outermost coke layer formed near the walls prevents excess heat entering the centre of the coal charge. Lower down the retort, the central portion of the coal charge is subjected to greater heating and the charge expands in the wider part of the retort. The main advantage claimed for this process is that uniform heating is achieved in a continuously moving charge without metal walls. Refractory brick walls are more lasting and there are no moving parts in the hottest zones.

5.5.2 Using weakly caking coals, throughput rates upto 10 tons/hr. are said to have been achieved. Caking or weakly caking slacks can be successfully treated. With the type of 'shock treatment' adopted, it appears that non-caking lump coals cannot be satisfactorily treated. The tar produced would have to undergo more cracking than in the other retorts previously described. The general operational data are presented in Table 4.

5.5.3 A pilot plant based on this process is contemplated to be installed at the Fuel Research Institute, Jealgora. It is also understood that the process might be modified to incorporate internal gas circulation based on the 'Rochdale' or 'Carrier gas' system developed in U.K.

5.6 *Koppers Retort*¹⁸: The Koppers retort, developed in Germany during the war, uses fire-brick walls, similar to that of Koppers High Temperature Oven and can be classified as a medium temperature carbonisation plant as the charge attains a maximum temperature of 800°C.

5.6.1 Heat is transferred to the coal through brick walls by burning gas in flues of silica brick and the coal continuously moves downward. Large quantities of steam are added below the carbonising zone which increase the gas yield and in conjunction with the undecomposed steam serve to augment the transfer of heat to the charge. Therefore in this method there is a combination of external and internal heating. This process cannot carbonise caking coals and is suitable only for non-caking and weakly caking coals.

5.6.2 A plant is claimed to have been in operation in Germany to process upper Silesian, high volatile, bituminous nut coal. During the war, two plants of 600 tons/day capacity were in operation in Japan. One of these plants consisted of two banks of 36 chambers each, divided into 6 batteries of 6 chambers. Each battery is 26' long with chambers, 12' 9" in length and tapering in width from 11¾" at the bottom to 10⅝" at the top to facilitate discharge of coke. The height of the carbonisation zone is 31'. It takes 21 hours for coal to pass through the unit. Regenerators are attached to the ovens and operate on a 30 minute cycle. Steam upto 60 per cent of the weight of coal charged is admitted. The addition of this steam increases the rate of heat transfer from the heating walls to the coal charge, increases the quantity of gas and decreases the carbonisation temperature to 700°-800°C. even though the flue temperature is as high as 1000°C. It is claimed that the coke is highly reactive in spite of greater devolatilisation. In both these plants, there was trouble of clinker formation in the lower section of the ovens, cracks in the wall permitting leakage of air and combustion of part of the semi-coke. The operational data are given in Table 4.

5.7 *Rexco plant*¹⁹: The National Carbonising Co., Ltd. and the Midland Rexaco, Ltd. in U.K. jointly operate this plant at Mansfield to produce smokeless domestic fuel. The process is based on L.T.C. of a static charge of coal at 700°C. in internally heated chambers of large capacity. The retort consists of a M.S. frame, lined with special quality refractory brickwork and is 24' high and 11' diameter with a capacity of 34 tons charge. A circular combustion chamber forms a dome on the top of the retort. Gas and air are admitted tangentially into the combustion chamber, air entering the outer circle being preheated during its passage. The movement of gas is centripetal and combustion takes place in the centre. It is stated that lighting up is very easy and carbonisation commences about 10 minutes after lighting. In the modified burner, part of the gas is burnt and the remainder mixed with the combustion products and this mixture now forms the total heating medium. The older burner

requires 8 hours for carbonisation, 7 hours for cooling and $1\frac{1}{2}$ hours for preparing and charging the retort. With the new burner the figures are 6 hours, 6 hours and $1\frac{1}{2}$ hours, respectively.

5.7.1 Normally weakly-caking lump coals can be carbonised in this retort. 23 tons of $2\frac{1}{2}$ "—4" material is charged first into the retort followed by 11 tons of 1"— $2\frac{1}{2}$ " material. Coal feeding is done through a telescopic chute which contracts with the rise in the coal level. The heating gases are drawn downwards through the charge, through a bottom grate and into the condensation system. The burner is operated till the charge is carbonised upto $\frac{2}{3}$ from the top ; then the burner is shut off and the gases are recirculated to carbonise the remaining $\frac{1}{3}$ charge by means of the sensible heat from the upper layers. The later operation is also called 'cooling' the charge. The product can thus be dry cooled almost completely and discharged by removing the grate bottom.

5.7.2 The general operational data (Table 4) indicate that the gas obtained is of low calorific value. The volatile matter in the coke is not stated. It however appears that due to the gradually reducing temperatures used during the cooling operation, coke from the bottom portion of the retort is likely to have more volatile matter than that from the top. During the first part of the operation, the top portions appears to get devolatilised to a greater extent than the lower portions as they are subjected to longer periods of heating. The plant is however, cheap to install and easy to operate. It is gaining importance in U.K. and more plants of this type are proposed to be installed.²⁰

5.8 *Lurgi-Spuelgas Plant*^{21, 22} : Among the internally heated processes, the Lurgi-Spuelgas process is perhaps the most widely used in the world. At the end of 1953, there were 220 Lurgi-Spuelgas units in operation all over the world processing in all 81,400 tons coal/day. About half the total number of ovens are processing bituminous coals and the other half, brown coals.

5.8.1 The plant consists of three sections arranged one above the other. The top section is the predryer into which sized coal is fed ; the middle section is the carboniser and the bottom section, the coke cooler. The sections are lined with refractory bricks and covered by M.S. Shells. In commercial size plants, units of 300-400 tons/day throughput capacity are multiplied. Each unit is divided into two halves with common burners for dryer and carboniser zones. The unit has a cross-sectional area of about $38' \times 20'$; the drying zone is about 23' high, carbonising zone 19' high, and the coke-cooling zone 16' high. The products of combustion from the burners enter the respective zones and form the heating media, flowing upwards through the coal charge. Provision is made for each section to withdraw gases at different levels and recirculate them into the zones after admixture with the products of combustion. A major portion of the recirculation gas is however, admitted into the coke cooling zone where it extracts the heat from the coke counter-currently and rises upward to join the heating medium admitted into the carbonisation zone. The coke leaves the plant continuously at about $40^{\circ} - 60^{\circ}\text{C}$.

5.8.2 The Lurgi-Spuelgas process is well suited for carbonisation of non-caking coals and it can also treat weakly caking coals. For this reason it has almost become a 'specific' for the treatment of brown coal briquettes. Like the Rexco plant, it is normally suitable only for the treatment of lumps above $\frac{3}{4}$ ". The coke obtained from the plant is strong and highly reactive. Due to uniform heating of the charge, even high ash non-caking coals produce a reasonably strong coke. The counter-current method of direct heating provides the best means of heat transmission. The gas pro-

duced from the plant is however diluted by the products of combustion. A large quantity of the gas is used up in the process itself. The general operational data on a Spuelgas plant are given in Table 4.

5.9 In addition to these well-developed processes, mention should also be made of the recent developments in fluidised carbonisation. Recent pilot plant trials in U.S.A.²³ have shown that by this method any type of bituminous coal can be carbonised and depending upon types of coal giving yields of 22-27 gallons tar, 3-4 gallons light oil and 1300-1450 lbs. char per ton of coal. The char can be used as a boiler fuel or for gas making or as a chemical reducing agent. This method is claimed to be ideal for non-caking bituminous coalfines; detailed operational data are however not yet available.

5.9.1 A similar plant processing lignites, with a capacity of 7,000 tons/day, has been reported to be operating at Aluminium Co. of America in their Texas plant²⁴ and an overall thermal efficiency of 91 per cent has been claimed for this fluidised carbonisation.

6. Although the above mentioned plants have been in existence in various parts of the world, L.T.C. has not yet taken any roots in this country. Attention of Indian Scientists was first drawn to the L.T.C. industry by the late Dr. H. K. Sen in 1940²⁵. He pioneered the installation of a small L.T.C. plant at the Lac Research Institute, Ranchi; this plant is still in operation to supply fuel gas to the Institute. Two more plants, one of the Kollergas type and the other based on Dr. Sen's design were contemplated to be installed but never went into production. On the other hand, more than one million tons of 'soft coke' are being produced annually by the wasteful method of 'open stack heating' entailing the loss of all the valuable tar.

6.1 About five years ago, the Central Laboratories for Scientific and Industrial Research, Hyderabad Deccan, decided to study the possibilities of subjecting the non-caking Hyderabad coals to L.T.C. on a pilot plant scale. On the basis of the general properties of the Hyderabad coals, the Lurgi-Spuelgas plant was chosen for the purpose. It was considered that the local high ash non-caking coals could be most satisfactorily treated in an internally heated type plant. In order to study the economics and future possibilities of the industry it was considered necessary first of all, to install a suitable size pilot plant in the Hyderabad city itself so that the semi-coke produced from the plant could be marketed in the Hyderabad and Secunderabad cities and the reactions of the public studied.

6.1.1 On economic considerations it was decided to install a 25 tons/day pilot plant at the Central Laboratories. The plant was put into operation in December 1953 and has since been in intermittent operation to supply semi-coke regularly to the local population. So far nearly 4,000 tons of coal have been carbonised and about 2,200 tons of semi-coke marketed. The semi-coke is being sold as a smokeless domestic fuel under the trade name 'Coalsite'. The details of specifications, operation and economics of the Hyderabad plant were already discussed on an earlier occasion.²⁶

6.1.2 Two types of coals were tested in the Hyderabad plant. Some of the general results obtained in the tests are presented in Table 5. Further tests on the influence of the temperature, size of feed and carbonisation time on the products are under progress. The studies made so far on the Lurgi-Spuelgas plant at Hyderabad clearly indicate that a satisfactory smokeless and reactive fuel can be produced from high ash non-caking coals. The coke was sufficiently hard to pass through all the stages of conveying, screening, shovelling and transportation to depots in lorries.

Although in its general fuel properties it stands out better than the 'soft coke' produced in the 'open bhattas', in its hardness 'coalsite' is poorer mainly because it is produced from non-caking high ash coals which weaken considerably on carbonisation. The 'soft Coke' from open 'bhattas' on the other hand, is produced from high ash slacks from caking or weakly caking coals.

TABLE 5.

Results of Pilot Plant Tests with Hyderabad Coals

	<i>Kothagudium coals</i>	<i>Tandur coals</i>
Analysis of Feed Coal :		
Moisture	5.1%	6.3%
Ash	19.6%	19.9%
Volatile Matter	26.4%	28.9%
Fixed Carbon	48.9%	44.9%
Calorific Value	10,550 BTU/lb.	10,170 BTU/lb.
Gray King carbonisation Assay		
<i>Yields per ton dry coal :</i>		
Coke	1712 lbs. (yields at 640°C)	1687 lbs. (yields at 650°C)
Tar	15.675 gal.	34.55 gal.
Liquor	16.35 gal.	15.88 gal.
Gas at 60°F and 30" Hg ...	3497 cu. ft.	3931 cft.
Analysis of 'coalsite' :		
Moisture	2.8%	2.5%
Ash	22.6%	25.7%
Volatile Matter	8.1%	8.1%
Fixed carbon	66.5%	63.7%
Calorific Value	11,435 BTU/lb.	11,000 BTU/lb.
Operational Data :		
Coal charged	25.25 Tons/day	25 tons/day
Coal for boiler	900 lbs/day	900 lbs/day
Power	1200 KWH/day	1,200 KWH/day
Water	10,000 galls/day	10,000 galls/day
Size of coal feed	+1" 68.4%, 1"-½" 24.1% -½" 7.5	+1"
Yields :		
Coalsite +1"	9.59 tons/day	13.58 tons/day
1" to ½"	3.66 tons/day	1.1 tons/day
-½"	3.84 tons/day	1.35 tons/day
Total	17.09 tons/day	16.03 tons/day
Heavy tar	132.7 gals/day	243.48 gals/day
Light tar (Middle oil) ...	173 gals/day	167.2 gals/day
Liquor	463.5 gals/day	544 gals/day
Surplus gas	96,000 cft/day of 120 BTU/cft.	77,000 cft/day of 90 BTU/cft.
Temperature of Carbonisation	640°C.	650°C.
Temperature of Predryer ...	200°C.	190°C.
Pressure in the carboniser ...	1.4" water	2" water

7. *Products from tars and liquors :* The primary purpose of L.T.C. is to produce solid smokeless domestic fuel ; large quantities of tar and oil are however produced as by-products. As mentioned previously, if the proposed L.T.C. projects in different regions materialise, about 360,000 tons L.T. tar and oil would be available. Considerable work has been done and is still in progress in many countries on the chemical nature of L.T. tar. Important chemicals, some of which form the starting materials for the synthesis of valuable substances, have been identified in L.T. tars

and oils. Apart from pure chemicals, it is also possible to produce road tar, pitch, creosote oil, etc. from L.T. tars and oils.

7.1 Very few L.T.C. plants are integrated with tar distillation and chemical plants. As far as is known, only the Coalite and Chemical Products Ltd., at Bolsover (U.K.) recovers fine and pure chemicals from L.T. tar.^{11, 12, 27} The New Zealand plant²¹ is interested only in the production of pitch and recovery of waxes. The Disco tar⁷ is treated only to recover the tar acids. The latter, however, have plans to establish a tar distillation plant to recover chemicals. Except for the recovery of tar acids, brown coal tars in Germany are not being processed for chemical recovery ; during the war the entire quantity was processed to produce motor spirit, diesel oil and waxes. L.T. tar produced from bituminous coals at Polish Plant²⁸ is reported to be treated only to recover pure phenols and paraffins and the rest is processed for fuel and diesel oils. Low temperature tar distillation industry, is, therefore, not yet set to recover fine chemicals. Indications for the future are however bright.

7.2 In the Central Laboratories at Hyderabad, we have been studying the possibilities of processing the tars produced in our pilot plant to obtain some of the products mentioned above. Very soon, we shall be installing a tar distillation plant of 3 tons/day capacity based on the designs kindly supplied by Carl Still and Co., Germany and modified by us to suit our requirements. It is intended to produce in this plant different commercial products like light oil, heavy oil, creosote oil and pitch for direct sale as well as for the recovery of tar acids, production of diesel oil, etc. Laboratory investigations are in progress to obtain higher yields of pitch for road tar preparation by air or gas blowing. It is found possible to increase by 50 per cent the yield of pitch with a softening point of 70°C. by blowing air through tar at 250°C. Studies are also being undertaken to recover pure tar acids from tar oils and aqueous liquors by conventional methods. Work on the fractionation and chromatographic identification of tar acids from oils and liquors is also in progress.

7.3 The general methods of utilisation of L.T. tar were reviewed in an earlier paper.²⁶ One aspect deserves emphasis. Considerable interest is being taken in the thermal treatment of L.T. tar to aromatise it and to recover the valuable aromatic chemicals from the same. A Japanese attempt to subject L.T. tar fraction to destructive hydrogenation over a molybdenum catalyst to produce highly aromatic gasoline (78 O.N.) has been reported.²⁹ According to a British Patent³⁰ low temperature tar oils are converted into aromatic hydrocarbons and a gas rich in ethylene by heating them at about 450-600°C. over catalysts containing at least two of the three oxides, molybdic, chromic and ferric oxides, activated with vanadium pentoxide. 80 per cent yield of aromatics is claimed. It has been reported³¹ that lignite tar can be cracked thermally at 750-900°C using H.T. coke as catalyst to yield highly aromatised tar and light oils containing benzene and its homologues. Jones and Neuworth³² reported the cracking of high boiling tar acids (230-300°C) in presence of superheated steam at 670°-850°C to yield low boiling tar acids (below 230°C) upto a maximum of 17 per cent on feed material. Brown coal L.T. tar was cracked³³ over silicon carbide + Al₂O₃ pebbles at about 800°C. to produce ethylene and aromatics such as naphthalene, benzene, etc. It can thus be seen that low temperature tar can be directly processed for special products and the residual oils can be cracked to increase the aromatics.

8. With what has been stated earlier it would be clear that enormous possibilities exist in this country for the development of low temperature carbonisation industry. On the basis of the types of coals available in our

<i>Material.</i>			<i>Process.</i>
1. Lignite Briquettes	..	..	Lurgi Spuelgas
2. Non-caking coals:	Lumps	..	Lurgi Spuelgas ; Rexco
	Slacks	..	Fluidised Carbonisation
3. Weakly caking coals:	Lumps &		
	Briquettes		Lurgi Spuegas, Rexco, B.-T.
	Slacks	..	B.T. Krupp Lurgi, Narrow
4. High ash, caking coal:	Slacks		Brick Retorts (F.R.B.), Fluidised Carbonisation, Disco.

8.2 On the basis of the pilot plant experiments conducted at Hyderabad, a proposal was submitted to the Government of Hyderabad for the establishment, under the Second Five-year Plan, of a L.T.C. plant at Kothagudium collieries to carbonise 800 tons coal per day. The following are some of the salient features of the proposal :

8.3 Details of proposals from other States are not known. The proposal recommended for lignites in South Arcot has been already referred to. This has the following salient features :³⁴

Cost of Production : Rs. 43-13-0 per ton carbonised briquettes.

8.4 In case the proposed synthetic petrol project involves hydrogenation of tar, it would be necessary to establish L.T.C. plants to carbonise

1 million annual tons of coal. Even otherwise it is necessary to stop the present wasteful method of 'open stack' carbonisation practised in the North Indian coalfields.

9 *Conclusion*: In conclusion I would like to state that in order to prevent the continued impoverishment of our soil and the extensive deforestation and destruction of our vegetation, it is imperative to provide alternatives to farm waste and firewood as domestic fuels. A beginning towards this can be made immediately by the setting up of 5-6 L.T.C. plants in the different coal-bearing areas of the country to provide about 2 million tons of smokeless semi-coke utilising our abundantly occurring deposits of low grade coals and lignites. This production can be expanded during the next 10-15 years, as envisaged by Lahiri⁶, to a production of 20 million tons of semi-coke. The setting up of the L.T.C. industry on this scale will also make available to us materials—coal slacks, tar and tar acids—which will form the starting point for the production of cheap thermal power, fuel gas and synthesis gas for synthetic ammonia and synthetic petrol, besides diesel oil, waxes and a variety of chemicals. This is almost the only rational and perfectly possible and feasible way I can see at present of coming out of the "cowdung age."

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SECTION OF GEOLOGY AND GEOGRAPHY

*President :—*A. M. N. GHOSH, B.Sc. (Hons.) (Lond.), A.R.C.S. (Lond.).

PRESIDENTIAL ADDRESS

RECENT ADVANCES ON GEOLOGY AND STRUCTURE OF EASTERN HIMALAYA

INTRODUCTION

It is a great occasion in the career of a professional geologist in this country to be elected President of the Geology and Geography Section of the Indian Science Congress Association. I greatly appreciate the honour you have done me and I thank you.

The subject chosen for my address deals with certain aspects of Himalayan geology as they presented themselves in the course of my own work in the Sikkim-Darjeeling Himalayas and those of my colleagues Messrs. B. Laskar, S. N. Sen, G. N. Dutt and T. Banerjee, in the Geological Survey of India, who are working under my guidance in the Sikkim and Assam Himalayas for the last few years.

The major portion of the area consists of metamorphic and igneous rocks. The absence of fossiliferous formations has rendered difficult the task of correlation and structural interpretation. In recent years attempts have been made in Sikkim and Darjeeling Himalayas to classify the metamorphic rocks according to different grades of progressive metamorphism and to find a way for structural interpretation with the help of the isograd lines that have been delineated. The last word has by no means been said and it is hoped that with the progress of work that has commenced fresh light will be thrown from accumulated data.

The area covered by systematic mapping has been extremely small and has been attempted only in certain selected areas. Whatever knowledge we have of the geology of the interior of the terrain has been gleaned from observations made in the course of traverses in various sections. We are also indebted to those explorers, mountaineers and scientists, who have wandered far and wide to wrench the secrets of the mighty range even at the cost of their lives.

I have used the term Eastern Himalaya to include the portion of the mighty range lying between Katmandu on the west and the Lohit river gorge in the Mishmi Hills on the east. A large part of the area still forms a blank on the geological map of India.

RESUME OF THE GEOLOGY OF THE EASTERN HIMALAYA

The Eastern Himalaya, like its western counterpart, is roughly divisible into four zones from south to north viz., (1) the sub-Himalaya, (2) the Lesser Himalaya, (3) the Great Himalaya, and (4) the Tibetan zone.

The sub-Himalaya forms an autochthonous zone consisting of folded unfossiliferous Tertiary sandstones and shales fringing the foothills of the border zone throughout its entire length, except for a gap of about 50 miles in North Bengal lying between the Chel, Jaldhaka and Torsa rivers. Here the Gondwanas and Daling phyllites abut against the *terai* plains.

The Tertiaries are over-ridden, on a thrust plane, in an inverted sequence by older rocks namely, the Gondwanas, Buxas and Dalings in the order mentioned. The thrust plane is known as the Main Boundary Fault of the sub-Himalaya. At places it is warped and folded.

The rocks of the Buxa series, so well developed in the type area (Darjeeling Himalayas), are not continuous as those of the apparently underlying Gondwana and overlying Daling formations in the Outer Himalaya. The absence of these rocks for certain stretches may be due to either structural disturbances and subsequent erosion or original lenticular nature of the bands or both.

The Lesser Himalaya forms a para-autochthonous unit consisting mainly of unfossiliferous dolomites and limestones (Buxa) and low grade metamorphosed sediments (Daling) and their granitised members and undoubted gneissose granites. All these rocks are considered pre-Cambrian in age. The metamorphic rocks overlie the Gondwanas in juxtaposition with the basal pebble beds of the latter suggesting that the normal order of superposition has been reversed. Everywhere in the Lesser Himalaya high grade metamorphic rocks overlie less metamorphosed ones. As a result of the erosion of the upper limb of a gigantic recumbent fold, the median limb of which forms the para-autochthonous zone with the root lying in the Central or Great Himalaya, the less metamorphosed rocks have been exposed in the lesser elevations the upper reaches of which are occupied by the high grade metamorphic rocks. The para-autochthon represents the overturned northern border of the Gondwanaland lying at the southern margin of the Tethyan geosyncline.

The para-autochthonous zone extends into the Great Himalaya, which consists mostly of gneisses and granites of different ages. Between Mt. Everest and Lhonak country in Northern Sikkim a normal succession of various grades of metamorphic rocks are found to underlie undisturbed sedimentaries of Permo-Carboniferous age. They represent the northern limb of the gigantic recumbent fold.

North of Mt. Everest these rocks have gentle northerly dips and underlie gently dipping marine sediments of the Tibetan zone ranging in age from Permian to Eocene at elevations of 15,000 feet or more.

The high grade gneissic rocks of the Great Himalaya support the unaltered younger sediments of Tibet and are themselves supported by the low grade meta-sediments followed downward by still less or almost unmetamorphosed Permo-Carboniferous rocks of the Lesser Himalaya. This indicates, as Heim has remarked, the highest mountains correspond to the back of the largest known thrust fold of our globe!

RECENT ADVANCES

(a) Geological

An outstanding geological discovery in recent years is the occurrence of a Lower Gondwana coalfield in the Rangit Valley in the heart of the Lesser Himalaya in Western Sikkim (Ghosh, 1952). The coalfield occurs as a window, having been exposed by the erosion of the overlying Buxa dolomites and limestones and Daling phyllites. The Gondwana beds consist of coarse-grained, gritty, light and grey feldspathic quartzitic sandstones

and carbonaceous shales. The beds have a 'boulder bed with tillite' near the base and coarse sandstones, shales and thick seams of semi-anthracitic coal in the upper parts. The pebbles are of various sizes and shapes and consist of gneiss, granite, quartzite, phyllite, chert and limestone, the last named having a Buxa appearance. At several places similar pebble beds have been observed at the base of the Gondwanas of the Outer Himalaya. A thick pebble bed of this nature, containing marine fossils, has also been recorded in the Great Himalaya by Wager (1933) at the base of his Permo-Carboniferous Lachi series at a height of over 18,000 feet above the sea level. The 'pebble bed' is now generally regarded as equivalent to the glacial Talchir boulder bed at the base of the Lower Gondwana formation of the Indian Peninsula. The Rangit Valley pebble bed thus indicates an erosional hiatus between the Gondwana and the older rocks, the latter forming the pavement on which the Gondwanas were deposited. The Gondwanas always dip under the Buxa limestones where these are present otherwise they dip under the Daling phyllites. The Rangit Valley Gondwanas are highly folded and intruded by dykes of lamprophyre and orthoclase porphyry.

Near Khemgaon in south-west Sikkim, Banerjee collected some stray marine fossils in the Gondwana country (Ghosh, 1953). Later, Dutt located the marine band *in situ* in the pebble beds at Khemgaon and Wak. The fossils collected have been identified as *Spirifer* sp., *Eurydesma* sp. and *Fenestella* (?). The sandstone and carbonaceous shales above the pebble bed have yielded the characteristic Lower Gondwana plant fossils *Schizoneura* and *Vertebraria*.

For the first time, thanks to Banerjee, the Gondwanas of the Outer Himalaya of Assam, have yielded impressions of *Glossopteris indica* in Kameng Frontier Division (Jacob and Banerjee, 1954). He has also recorded the occurrence of boulder slates at the base of the Gondwanas of this area. Further east in Subansiri area, Laskar has located fossiliferous marine bands, five in number, in association with fresh-water Gondwanas. Some of the fossils identified are *Chonetes* sp., *Productus* sp., *Spirifer* sp. and *Conularia* sp. and crinoid stems. The presence of *Eurydesma* and *Conularia* definitely fixes the age of the basal Gondwanas of the Eastern Himalaya as Permo-Carboniferous and recalls to mind the marine Gondwanas of the Kashmir Himalaya.

The marine fossils of Subansiri and Southern Sikkim bear resemblance to those collected by Wager from the Lachi Hills in North Sikkim, suggesting southward extension of an arm of the Lachi sea. Oscillation of the sea floor was responsible for interbedding of marine with fresh-water continental sediments in Subansiri area. Association of marine fossils with Talchir boulders indicates that the pebbles were dropped by floating icebergs in an open sea near the southern edge of the continental shelf of the Tethyan geosyncline.

Volcanic rocks have also been recorded in undoubted Lower Gondwanas of the Assam Himalaya. Laskar came across agglomerates, tuff and lava flows associated with the lowest beds of the Gondwanas in the Subansiri area. The volcanics may be equivalent to those of the Abor Hills. There are, in addition, minor intrusions of lamprophyre, orthoclase porphyry, etc. into the Gondwanas. In Kameng Frontier, Banerjee has recorded the presence of tuffs within the Gondwana and immediately above the Talchir boulder slates. The association of volcanic materials with the Lower Gondwana beds in these areas suggests that the eastern part of the Eastern Himalaya witnessed volcanic activity along a

zone of tension about the same time as its western counterpart in the Kashmir Himalaya.

In the Mt. Everest region Dutt, who accompanied Shipton's Reconnaissance Expedition for a southern route to Everest, noticed an inversion of metamorphic zones in the schists and gneisses in that region. According to Dutt the upper parts of ridges are invariably occupied by high grade metamorphic rocks while the low grade members are confined to lower heights and the bottom of the valleys.

(b) Geographical

Credit for a striking geographical discovery in Eastern Himalaya goes to Shipton's reconnaissance party of 1951 (Shipton, 1952).

About 30 miles west of Mt. Everest, the party moved into a group of high mountains whose position in relation to the main range was difficult to determine. From the south flowing glacier system which the party met on crossing the col which was named Menlung La, the mountains appeared to represent the southern side of the main range. But further exploration in the surrounding region revealed a vast amphitheatre, like the Nanda basin, in the centre of which was found a peak isolated from the main massif and higher than Gouri Sankar. This peak was named 'Menlungtse'. The waters of the basin actually flow northwest and plunge directly into a system of tremendous canyons. This has given rise to one of those remarkable rivers which, like the Arun, rise far to the north on the Tibetan Plateau but cut their way transversely through the Great Himalayan Range.

Similar exploration to the southern regions of the Mt. Everest by the same party shows that the upper basin of the Imja is contained on the north by the Nuptse-Lhotse wall and on the east and south by dozens of unnamed peaks the heights of which range between 20,000 and 24,000 feet high (Shipton, 1952).

(c) Heights of the Himalayan peaks

Controversy regarding the recording of correct heights of the snow peaks of the Himalaya, by geodetic and other methods, cropped up again after the highest peak Mt. Everest was conquered on May 29, 1953. On the assessment of the determinations of these heights, according to modern standards, the work done in the past about a century ago leaves scope for further improvement. Fresh observations on systematic lines, taking into account the various factors governing the accuracy of such determinations, are necessary for checking up and correcting the values so far considered 'accepted'. Short-sided triangulation closer to the peaks can naturally get more reliable values of the heights than that from stations in the border regions of the plains. Gulatee (1952) has suggested that the chain of minor triangulation run in Nepal, to provide controls for mapping the Kosi catchment area, may be extended further to the north to provide suitable stations at reasonable heights for taking vertical angle measurements of Mt. Everest.

The recent field observations by the Survey of India taken in connection with the determination of the revised height of Mt. Everest (29,028 feet) indicate that the correct heights of Kanchenjunga and Makalu could be increased from their accepted values by some 30-36 feet (Wilson, 1955). However, much work remains to be done before the correct values for the peaks in this large area can be given.

(d) *Problems relating to Recent uplift of the Himalaya*

A common belief originating from geological studies that the Himalayas are still in the process of rising has led some to consider erroneously that the difference of the values in different determinations is due to the same reasons. In fact, though a great mass of geological data has been advanced to testify that the Himalayan uplift is continuing even to this day, the evidences provided by the different values of heights obtained from uncertain determinations at different times are not meant to confirm the rise. Variation of the height, if any, can only be determined by carrying out repeated vertical angle observations of the peaks from one station and under similar conditions. Repeated observations taken in 1932-33 on some of the lesser peaks, however, do not show any measurable changes in the heights previously recorded in 1807-08. But again, this is too short a space of time for such movements to be of a measurable degree. Practically undisturbed condition of Pleistocene beds at places like Nagri Khorsum obviously suggest no violent disturbance of the Himalayan region since that period (Burrard and Hayden, 1933). This apparent period of quiescence, however, may be just a comparatively feeble phase of the still continuing imperceptible earth movements which may cause the Himalaya to rise further. The frequent tectonic earthquakes occurring in the Himalayan region testify that the region is still in an unstable state and that the mountains are undergoing movements either vertical or horizontal or both.

Evidences of slow secular upheaval are best displayed in the sub-montane tract east of the Tista valley, especially in the region on either side of the Jaldhaka river near Matiali. In this fore-deep area of the mountain chain, Quaternary terraces rise gradually northward. Five such terraces, composed of gravels and boulders, have been recognised one mile west of Chalsa railway station. Some of these terraces, of which the uppermost is the best developed and most extensive, rise to a height of 300 feet above the floor of the valley (Heim and Gansser, 1939). A slight warping is noticeable in the terraces between Nagrakata, Matiali and Samsing, suggesting vertical movement. Some of these terraces carry gneissic boulders of extra-ordinary size brought down either by glaciers or rivers. Similar terraces were recorded by me in the Mishmi Hills in the Dibang gorge north of Nizamghat, several hundred feet above the river bed and also in the Luhit Brahmaputra, west of Brahmakund and are not uncommon in other parts of the Assam Himalaya. They have been regarded as alluvial fans of the Himalayan streams coalescing to form a great piedmont apron, but N. R. Kar (1955) has recently thrown some doubt on its fluviatile nature. He considers them to be due to glaciation.

OBSERVATION AND INFERENCE

In support of what has been said before let us piece together the evidences collected so far. This I shall do by briefly reviewing the geological features of the different sectors of the Eastern Himalaya beginning with Sikkim and Darjeeling terrains.

(a) *Sikkim-Darjeeling Himalaya*

The Great Himalaya Range, aligned E-W in Northern Sikkim, supplies the waters of the Tista river and forms the Kanchenjunga-Pauhunri massif. Two arms, one from the western and the other from the eastern ends of the massif, project southwards and gradually descend on the *bhabar* land lying at the northern end of the North Bengal plains. The Singalila

Range forms the western arm and the Dongkya Range comprises the eastern one. The main watershed of the Tista is thus folded into the shape of a horse-shoe of gigantic size the convex side of which points northward and the two limbs southward. Gneissic rocks comprise the arch-shaped watershed. Gneisses on the western and eastern limbs dip respectively westward and eastward and those on the north, along the E-W range forming the crest of the fold, dip northward. This is thus a tectonic ridge brought about by folding, uplift and erosion. The Tista draining the central portion of the horse-shoe has resulted from a direct consequence of its uplift. A similar arc, though rather distorted, is present in Eastern Nepal forming the watershed of the Tamur river. Arch-shaped spurs having a southerly sweep but of a much smaller magnitude are thrown out in the Sikkim and Darjeeling Himalayas from the two main N-S arms mentioned earlier. The most conspicuous of the former is an offshoot of the Singalila Range which supports the town of Darjeeling.

South of the parallel of latitude $27^{\circ}32'$, the central portion of the arch-shaped watershed of the Tista is occupied by a wide expanse of metamorphosed sediments of the shape of a spear-head the tip of which points northwards. There is a remarkable parallelism of the Sikkim arc with the dome-shaped exposure of Daling rocks. The unfossiliferous slates, phyllites, low grade chlorite and sericite schists and quartzites of the Daling series are surrounded on all sides by garnet, staurolite, kyanite and sillimanite bearing schists and gneisses and are found to dip under the latter. Like the Tertiaries and the Gondwanas which they overlie, the Dalings fringe the foothills of the Darjeeling and Kalimpong hills. Along the Tista valley a narrow neck of the Daling rocks connects the northern exposures in Sikkim with those of the Outer Himalaya in the Darjeeling district. The Tista valley, flanked by the Darjeeling hills on the west and the Kalimpong hills on the east, has been carved along the crest of an anticline with a northerly pitch. The core of the fold is occupied by Gondwana rocks and the flanks by the Dalings, which grade upwards into Darjeeling gneiss. Due to a reversal of pitch, possibly brought about by upthrusting, a small patch of Gondwana is exposed in the interior at Tarkhola, about 15 miles north of the foothills belt.

The wide expanse of the Daling dome in Central Sikkim is possibly due to an upwarp and represents the northern sector of a major anticlinal fold the southern part of which is exposed as the narrow neck in the Tista valley and forms the downthrow side of an E-W fault trending through the Ramman and Rangit rivers at the toe of the Darjeeling hill.

It has been noted by previous workers, namely Mallet, Bose, Holland, Fermor, Heron, Auden, Dyhrenforth, Wager and others that the Daling phyllites pass gradually into the overlying Darjeeling gneiss through mica-schists (Auden, 1936). From the disposition of the Daling phyllites on the top of the Gondwana beds in Darjeeling area it was suggested by Mallet, Bose and Holland that the apparent position may be due to inversion but the relationship with the overlying Darjeeling gneiss, was not elucidated. Fermor thought that the Daling series was infolded with the Darjeeling gneiss but Auden suggested that the former is likely to represent a big sedimentary succession the upper part of which has been metamorphosed into gneisses by injections of granitic material acting under stress. From a traverse in Northern Sikkim Auden (1936) suggested that it would be possible to work out a sequence of metamorphic zones in the Darjeeling gneiss.

From traverses made in Darjeeling and Sikkim hills, Heim and Gansser (1939) observed that the Darjeeling gneisses represent the meta-

morphic variants of the Daling rocks and supported their observation by chemical study. They concluded that the superposition of the gneisses on the phyllites was due to inversion. Their conclusion is in agreement with that of the Hungarian geologist Loczy who, from his own observation in 1878, concluded in 1907 that the position of the Darjeeling gneisses resting on the less altered Daling rocks is due to a major recumbent fold.

A sequence of zones of progressive metamorphism in the schistose rocks of the Darjeeling hills has been worked out by S. Ray (1947). With the help of the index minerals like chlorite, biotite, garnet, kyanite and sillimanite he delineated isograds for different zones. Backed by the results of chemical analyses he arrived at the conclusion that the Darjeeling gneiss was a metamorphic variant of the Daling phyllites.

During my traverses in Eastern and Western Sikkim in 1945 across the great dome-like exposure of the Daling rocks, exhibiting qua-qua-versal dips, I was able to detect gradual passage, both on the eastern and western sides, of the Daling rocks into the overlying micaceous schists. In the direction of dip the rocks show progressive metamorphism upwards.

In Eastern Sikkim it was noticed that from near their junction with the phyllites the schistose rocks carry in succession such minerals as chlorite, sericite, biotite, garnet, chloritoid, staurolite, kyanite and sillimanite. Using the incoming of these minerals one by one in the schistose rocks as an indication of a change in the grade of metamorphism, it was possible to work out an almost complete sequence of metamorphic zones in an ascending order, in which the sillimanite bearing rocks came at the top and the phyllites at the bottom. Bands of quartzite, graphite schist, calc-schist, calc-granulite and marble containing diopside and wollastonite were noticed amongst the rocks of the kyanite and sillimanite zones as also minor intrusions of basic rocks represented by epidiorites in the phyllites, hornblende schists and amphibolites in the schists of the higher grades. The rocks of the kyanite and sillimanite zones are profusely injected with granitic material, sometimes to the obliteration of these minerals. The different isograds trend N.N.W. The metamorphic zones are of variable width, the widest being the sillimanite zone consisting of banded sillimanite gneisses, biotite gneisses of granitic composition and augen gneisses.

All the higher ridges, Natu La-Jelep La ridge (14,000-15,000 feet) on the east and Singalila ridge (11,000-12,000 feet) on the west, are composed of rocks of the sillimanite zone. Their lower reaches are occupied by rocks belonging to kyanite and still lower zones.

Granitic rocks, some of which are highly sheared, are present in phyllites as well as in the garnet and staurolite zones. Soaking by granitic material is not, however, so intimate in the lower zones as in the higher ones.

The story is repeated in Western Sikkim ; but the isograds have northeasterly trend. Chloritoid is absent and staurolite is not so well represented. The entire absence of chloritoid and often of staurolite may be attributed to the lack of a suitable bulk composition in the original sediments suggesting therefore that chemical composition has direct bearing on the development of index minerals.

In Northern Sikkim, Banerjee and myself found the different isograds on the eastern side of the Daling dome running almost parallel to the boundary of the Daling phyllites as far as Mangen in a NNWly direction. On the northern side in the Talung Chu, the lines have northwesterly trend at first and then swing E-W, in front of the nose of the pitching fold, to converge with the isograds coming from the southwest lying on the western side of the same dome. Further north in the upper

reaches of the Lachen and Lachung valleys sillimanite becomes scarce in the augen gneisses and also in the biotite- and hornblende-gneisses which are of granitic composition. It is likely that these ortho-gneisses belong to the deeper levels below the sillimanite zone where extensive granitisation might have taken place.

From the gradual passage of the epimetamorphic slates through the mesometamorphic schists into the katametamorphic schists and gneisses, and from the behaviour of the isograds we may conclude that the whole sequence belongs to a great sedimentary succession which has been subjected to different grades of metamorphism at different levels, resulting in the formation of metamorphic minerals characteristic of the different zones.

Within the core of the Daling dome, in the Rangit valley between Naya Bazar and Wak, a band of dolomitic limestone, of variable thickness, intervenes, at places, between the basal Talchir tillite and pebble bed and the overlying Daling phyllite. The beds are highly folded as a result of which they are found in the river valley at an altitude of 1,000 feet as well as on the hillslopes at variable heights upto about 6,000 feet. The basal pebble bed, coming next to the Buxa and the Daling rocks, is also found at similar heights and follows the junction of the Gondwana and other rocks.

The occurrences of Lower Gondwana rocks, their marine equivalents and the older Buxa and Daling series at three different elevations in the Outer, the Lesser and the Great Himalayas are probably due to three phases of the uplift of the mountains. The earliest phase opened with a gradual uplift of the Tibetan basin and perhaps of the Kanchenjunga-Pauhunri massif in post-Eocene times. It was followed by somewhat violent upheavals of the Lesser and the Outer Himalayas. In the absence of fossiliferous rocks younger in age than the Gondwanas in the Rangit valley, the exact age of the different uplifts in Sikkim remains rather indefinite.

During the last five years my colleagues and myself have been engaged in systematic mapping of the different isograds, using chlorite, biotite, almandine garnet, staurolite, kyanite and sillimanite as the index minerals. It is found that the different isograds have a rough parallelism amongst themselves and also with the outer boundary of the Daling exposure, and they swing round the Daling dome in Eastern, Northern and Western Sikkim and also along the northern slopes of the Darjeeling hills. They are also parallel to the Daling exposures along the Tista valley and along the northern and southern slopes of the Kalimpong hills. At places the isograds have transgressed the stratigraphical boundaries suggesting that metamorphism has been selective and not confined to any particular stratigraphical horizon.

(b) *Eastern Nepal*

Daling outcrops, not unlike the shape of that in Sikkim, are present in the Tamur and the Arun river valleys in Eastern Nepal. Here also the Daling rocks dip under the gneisses on three sides in an anticlinal fashion, the Dalings forming the anticlines and the gneisses corresponding synclines. Although outside Sikkim-Darjeeling area the zones of progressive metamorphism have not been worked out, one can safely predict that they do exist in Nepal and elsewhere but the sequence may not be so complete as in Sikkim.

In the valleys of the Arun and the Dudhkosi rivers via Dharan, Dhankuta and Namche Bazar, Dutt noticed metamorphic gradation of the

pelitic rocks from the phyllites of the Tamur valley to the garnetiferous gneisses on the ascent to Dhankuta and again from the meso- and kata-metamorphic rocks to the epi-metamorphic phyllites on the descent to the Arun valley. The metamorphic grade again increases on the ascent to the Mayan Danda. The valleys of the Hongu and the Inuku *kholas* between the Arun river and the Dudhkosi basin display epi-metamorphic rocks while the intervening ridges are formed of kyanite schists and sillimanite gneisses. Sillimanite gneisses also occur at Jantra Khani near Okhal-dhunga and on either side of the Tamba Kosi valley at Syankhu and Sikpaser Khani, although the valley itself is composed of phyllites of the chlorite zone. In the Everest region at Dingboche the sillimanite gneisses are overlain by garnetiferous mica schists and granulites. The low grade rocks west of Everest are profusely intruded by stringers and stocks of tourmaline granite and aplite.

On another occasion in 1953 Dutt made a traverse between Dhankuta and Darjeeling via Taplejung, following the route taken by Auden in 1934. On the Hile and Gurase ridges he noticed garnetiferous mica schist overlain by and grading into sillimanite gneisses. A return was again made into low grade phyllites in the Tamur Section, west of Taplejung. On the ascent to the Singalila ridge along its western slope the grade of metamorphism progressively increases from epigrade phyllites to sillimanite gneisses.

In his traverses in Nepal, Auden (1936) also noticed a gradual upward passage of epigrade metamorphic rocks, which he regarded as Dalings, into overlying meso- and kata-grade metamorphic rocks, styled by him as Darjeeling gneiss. From this feature he suggested that the terms Dalings and Darjeeling gneiss may represent metamorphic grades rather than stratigraphical units. He thought that the increase in metamorphism upwards must have some connection with lit-par-lit intrusions of granite. From the occurrence of Ordovician Chandragiri limestones in a syncline resting upon rocks showing an increase in metamorphism downwards, Auden considered the Kulikhani granite would be either pre- or post-Ordovician in age depending on the existence or absence of an unconformity, which can only be detected after detailed mapping.

(c) Assam Himalaya

Coming to Assam, the Gondwanas of the Kameng area are overlain by Daling phyllites and other metamorphic rocks. According to Banerjee the contact does not show any sign of disturbance and he explains the reversal of the original order of superposition by overturning. At certain places near about the junction, injections of granitic material are noticed in the overlying phyllites and north of the Gondwanas there has been extensive development of mica gneisses displaying intermittent exposures of chlorite-phyllites, sericite-, biotite-, and garnet-mica-schists and quartzites of the Daling series. In his opinion the mica-gneiss has resulted from the granitisation of the Daling rocks. Far to the interior of the hills up to the Sela pass, at a height of about 15,000 feet, the degree of metamorphism shows a progressive increase carrying at the same time a succession of critical index minerals like staurolite, kyanite and sillimanite. The disposition of the metamorphic rocks in the areas, where the higher grade rocks overlie the lower grade ones, is comparable to that of similar rocks in the Sikkim-Darjeeling Himalaya.

In the Subansiri area also Laskar has noted a gradual passage of epigrade rocks into meso- and kata-grade rocks in the direction of dip. These

rocks overlie the Gondwanas. In one section he noticed a thick succession of variegated quartzites intercalated with maroon slates, wedged in by faulting between the Gondwanas on the south and Buxa dolomitic limestones on the north.

BEARING OF THE ISOGRADS ON REGIONAL STRUCTURE

Instances of inversion of the normal order of sequence of metamorphic zones as a result of post-metamorphic folding have been noted in many parts of the world. The mechanism of the process, however, has been in dispute.

From the facts enumerated so far, it will be seen that everywhere in the Eastern Himalaya low grade metamorphic rocks are overlain by rocks of higher grades. Further, where conditions are favourable, a gradual passage can be traced. In Eastern Sikkim a complete and well developed sequence of zones of progressive metamorphism has been worked out by drawing isograds of different zones. It may be possible to work out a similar sequence in other parts of the Himalaya as in Uttar Pradesh and the Punjab, where similar rocks are present. In areas where one or more zones are absent this may be explained as due to faulting or thrusting or extensive granitisation. As fossils are absent in these rocks structural interpretation can also be done by delineating the isograds of the different metamorphic zones and studying their behaviour. In this connection it may be borne in mind that lateral or vertical compositional variation of the original sediments will inhibit the formation of the critical index minerals.

From the above observations certain fundamental problems arise having a direct bearing on the processes of metamorphism and tectonics. In Sikkim we have inverted zones of progressive metamorphism on a regional scale. That there has been a structural inversion as well, is indicated by the highly folded Gondwana formation, exposed in a tectonic window, dipping under the Buxa or Daling formations as the case may be. The presence of a basal Talchir pebble bed at many places near the junction of the overlying Daling phyllites, whether on the higher hills or in the lower valleys, confirms the validity of such an inversion.

From the disposition of the para-schists and gneisses of Sikkim, where they surround the Daling dome, the core of which is occupied by the unaltered Gondwana sediments, it is hard to visualise any large scale permeation of granitic material under stress in the outer part of the Daling succession without affecting its interior. The uninterrupted extension of the lines of the different isograds over large areas precludes the idea of large scale thrusting. My own observations, in 1945 and in 1950, have led me to the conclusion that the high grade schists and gneisses represent the highly metamorphosed lower part of the Daling rocks which were originally composed of shales, sandstones and limestones.

The development of the metamorphic minerals was probably due to the rise of the isogeotherms in the subsiding Daling geosyncline and was also accompanied by injections of granitic material in the deeper zones. Thus successive zones of sillimanite, kyanite, staurolite, chloritoid and garnet would develop from the central part outwards. Such metamorphism may cut across the stratigraphic horizons as indicated in a few places.

The occurrence of the Daling phyllites and the Gondwana rocks in the core of the dome, flanked on all sides by rocks exhibiting a stratigraphical and metamorphic inversion can be explained by the erosion of an overturned fold. It was probably during N-S orogenic movements that the

metamorphic rocks were overfolded on a gigantic scale in a recumbent fashion and overturned on the southern side along an E-W axis thus causing the high grade metamorphic rocks of the lower part to rest on the less metamorphosed Dalings of the upper part. The overturned recumbent fold was later subjected to a transverse refolding along a N-S axis which formed the Daling dome as also the big semicircular watershed of the Tista river. Similar cross folding of the Gondwana and older formations is noticed in the Tista valley between Darjeeling and Kalimpong hills, where the Gondwanas occupy the foot of the hills and sillimanite gneisses the hill tops. Dome-shaped 'antiformal' (anticlinal) exposure of Daling rocks has been mapped in the Tamur valley by Auden with exposures of gneissic rocks in complementary synclines on both sides.

A problem facing us is the definition of the term Daling series and the age of the Darjeeling gneiss. Previous workers restricted the term Daling series to epi-metamorphic phyllites and schistose rocks. The aureole of meso-metamorphic rocks exterior to the former was mapped by them along with the kata-metamorphic gneisses as the Darjeeling gneiss. In conformity with established practice I have been using the term Daling series to include only the rocks of the chlorite and biotite zones. The coarsely foliated mica schists of the garnet and staurolite zones, in my opinion, should be grouped together and separated from the underlying Daling rocks on the one hand and from the overlying rocks, gneissose in character, of the kyanite and sillimanite zones on the other. From the extensive development of the rocks of the garnet and staurolite zones in the Rangli valley, west of Rangli in Southeast Sikkim, the name *Rangli schist* is proposed for this group of rocks. The term Darjeeling gneiss should be used only for the kata-grade rocks of the kyanite and sillimanite zones. In this context I would like to offer another suggestion that since we are now establishing a metamorphic succession we had better abolish the use of the term Daling series and instead, refer those rocks as Daling phyllite.

The age of the Darjeeling gneiss would be younger than that of the Daling series if Auden's interpretation is accepted that the former represents the metamorphosed upper- and so, the younger-part of the latter. I hope I have been able to prove convincingly that the sediments that were subject to high-grade metamorphism in post-Daling times are older than the less metamorphosed ones having been restricted to the lower reaches of the Daling geosyncline.

The older rocks above the Main Boundary Fault are highly folded and crumpled. S-shaped sigmoid folds having an E-W axis were observed in a cliff section in the Gondwana beds in Bagrakote coal-quarries south of Kalimpong. Acute recumbent folds with an E-W axis were noticed in a band of quartzite in the gneisses, 20 miles further west, in the quarries for road metal on the hillslope. This fold was followed to a depth of nearly 1,000 feet along the hillside between Gidda Pahar, near Kurseong and Gayabari. This folded quartzite band is probably a replica of the major regional fold. Similar acute folds have been noted by Banerjee in the Gondwanas of the Kameng area and by Laskar in the Subansiri area.

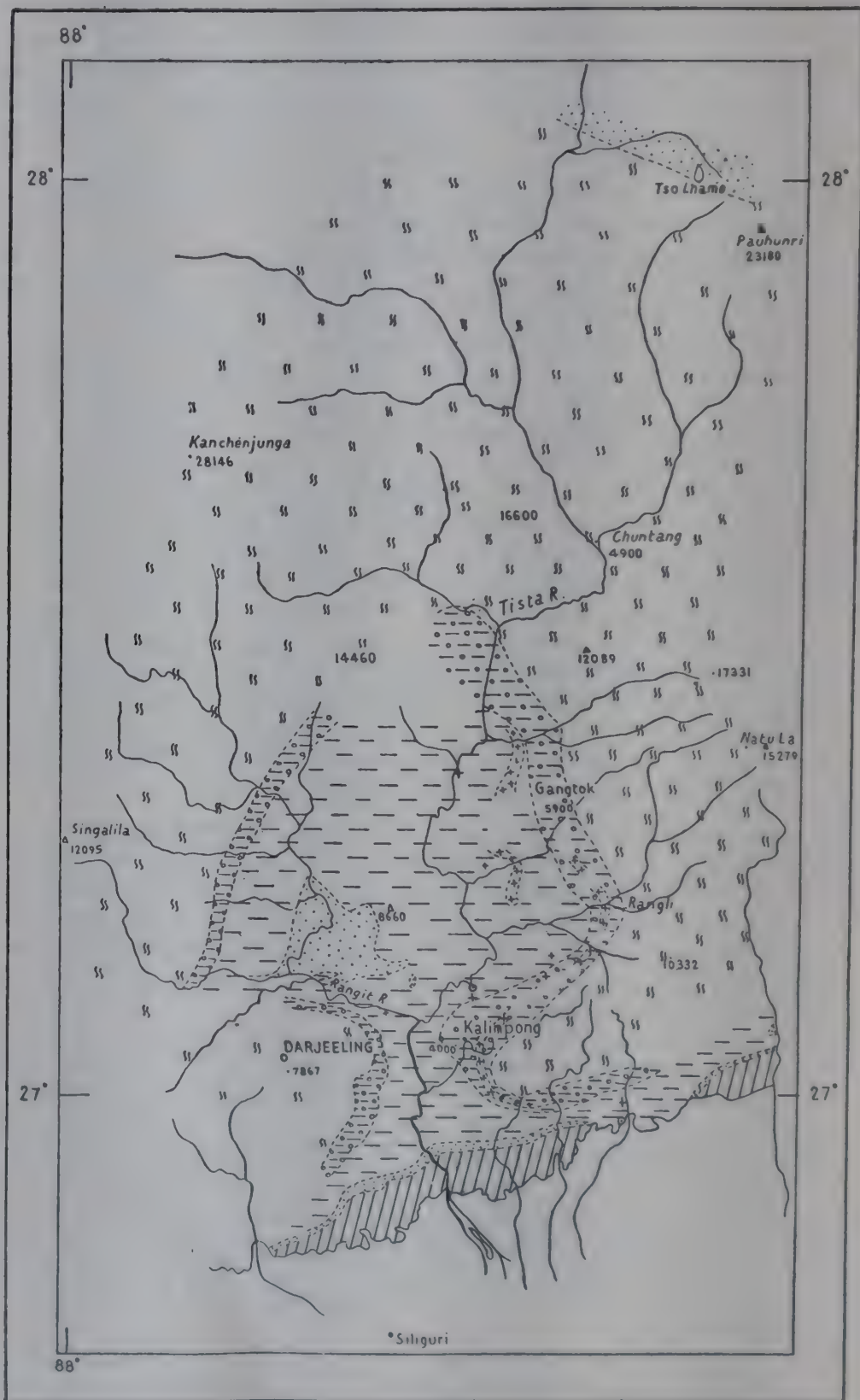
The presence of the Gondwana rocks below the Daling phyllites in the Rangit valley indicates that these fold movements are post-Gondwana in age and possibly older than the Tertiary rocks of the foothills. The N-S movements resulting in overfolding and overturning represent the earlier phase of the main orogeny of the Himalaya and were followed by E-W movements.

GEOLOGICAL MAP OF SIKKIM AND DARJEELING HIMALAYA.

After F.R. Mallet, L.R. Wager, P.N. Bose, A.M.N. Ghosh, S. Ray, S.N. Sen, .

G.N. Dutt & T. Banerjee

SCALE 5 0 5 10 MILES



INDEX.

Tertiary

Sheared granite.

Rangli schist
Garnet & Staurolite Zones.

Gorn'wana (including tachist)

Dalingsphyllite (including Buxa)
Chlorite & Biotite Zones.

Rangli schist
Garnet & Staurolite Zones.

Darjeeling gneiss
Kyanite & Sillimanite Zones.

All the tectonic and metamorphic events that I have dealt with so far form a part of the orogenic movements that have taken place in this sector of the Himalaya and it is necessary to review them in this general background so that we may appreciate their full significance. As can be readily seen from the geological map of this region the gently dipping broad folds of the Tibetan region are bordered by a southern zone of thrust overfolds which also show an inversion of the metamorphic zones. These upthrust folds have rolled over the underthrust block of the Gondwanaland.

It is admitted on all hands that the uplift of the Alpine-Himalaya system of folded mountain range is possibly due to movements, towards one another, of two crustal blocks of the forelands on either side of the Tethyan Geosyncline. The forelands acted like the jaws of a closing vice, underthrusting the geosyncline, and so causing the pile of the sediments to crumble up and splay out on both sides.

So far as the Indian side is concerned, it may not be too speculative to suppose that in pre-Tertiary times one set of rivers at the northern edge of the Gondwanaland used to flow northwards and deposit their load of sediments into the Tethyan sea. Due to the removal of large quantities of the material by the rivers there would be a load deficiency in the Gondwana foreland sector of the sial as a consequence of which isostatic equilibrium would be disturbed. Some convection currents may develop at the base of the geosyncline to effect the transfer of subcrustal material towards the unloaded mass. This process may result in the generation of the granitic magma in the critical zone and subsequently initiate the tectonic movements. It is likely that the lower portions of the pile of sediments, now represented by the Darjeeling gneiss, have been affected by a fresh cycle of synorogenic granitisation and metamorphism.

The northerly movement of the somewhat crumpled Gondwana foreland would cause folding and arching of a portion of the sediments in the upper part of the geosyncline. Some of these folds would be thrust deep into the region of palingenesis. Further, northerly movement of the Gondwana block and its underthrusting below the sedimentary cover would result in the extensive emplacement of granite along the core of the Himalayas. In the case of the Central and the Outer Himalayas this sialic material of the core may have been supplied by a northerly transfer of the material from below the northern edge of the crumpled foreland of the Indian mainland. Loss of material of this magnitude all along the entire northern edge of peninsular India, to support a mountain range, whose central axis reaches an average height of 20,000 feet above the sea level, would cause an extensive sagging and downwarping of the crust in front of the mountains. It is possible to explain the depression known as the foredeep of the Himalaya, now filled by the alluvium of the Indus, the Ganga and the Brahmaputra, by such a process.

From the downwarp of the crust between the present Himalaya and the peninsular India,, it would appear that a considerable width of the northern edge of the Gondwanaland was involved in the Himalaya orogeny. An early effect of the northerly movement of the foreland towards the geosyncline would be to throw the rocks in front of it into gentle ripples and open folds affecting the frontal part of the foreland as well as a portion of the sediments in the geosyncline. These folds would become sharper and sharper as the jaws of the vice closed in. Near the edge of the geosyncline anticlines and synclines would be formed while further away in the direction of the geosyncline the folds would be more shallow and open. As the compressional forces are continued

the anticlines and synclines would pass into isoclinal folds and with the increase in directional pressure the isoclinal folds would overturn as recumbent folds and fall on that side where there would be least obstruction. As now we find that the folds have been overturned to the south it may be presumed that the peneplaned Gondwana foreland was the side of least resistance due to downthrust movements. With increasing intensity of the compressional movements there would be the thrusting and translation of folded rock sheets along thrust planes over long distances, as has been the case in the U.P. and the Punjab Himalayas. Such an interpretation of the tectonic evolution is quite in accord with the structural disposition of the rock formations seen in the Sikkim region.

The Great Himalayan arc in Northern Sikkim may be explained by the continued forward northerly movement of a protruding wedge of the upturned Gondwana foreland before the sediments in the central part of the geosyncline were elevated sufficiently high to offer resistance to the moving block. The movement seems to have a pronounced vertical component. The broad warps affecting the outcrops of Daling rocks in the Tamur anticline and of the gneiss in the Dhankuta syncline may be likewise explained. A succession of sharp northward movements, one after another, would telescope the folds and give rise to a chain of parallel arcs at different heights as noticeable in Kabru-Pandim massif and in the Darjeeling Himalaya.

So far we have considered the structural evolution and the metamorphism of these rocks and their relation to the regional orogeny. However, when we consider the age of the various formations and the sequence of the various events that have taken place some difficulties arise. The Dalings are considered to be pre-Cambrian in age. If so, it is possible to visualise a pre-Cambrian metamorphism below the Daling geosyncline resulting in the development of the metamorphosed rocks. A second alternative would be to visualise the metamorphism and the inversion in a continuous process, in which case the metamorphism of the Dalings would be post-Gondwana and not of the pre-Cambrian period. This would mean that the metamorphic processes which were more active at the lower horizons of the Dalings, did not reach the upper portions which have remained unaffected. Further investigations will show which of these alternatives holds good.

The formation of the festoon-like arc in front of the Himalaya, overlooking the foredeep can be explained by the northward movement of the peninsular block during the final phase of the uplift of the mighty range. It is unlikely that the southward drift of the Angaraland, on the northern side of the broad Tethyan geosyncline, would be able to exert such pressure along the southern edge of the latter as to bend the strata of the Outer Himalaya by overcoming the force set up by the northward movement of the peninsular foreland. The fold patterns on the broad Tibetan plateau and the Sikkim arc do not support any such contention. On the other hand, it seems possible for the elevated young mountain range to act as a rigid mass of the nature of a horst and offer resistance to the waning forces directed from the south. This would cause the foothill belt to bend round the median mass. It was where the force from the north was greater than that from the south, that the strata bent round the foreland wedge as in the Kashmir Himalaya.

An important aspect in the study of metamorphism of the Himalayan rocks is the survival of the typomorphic minerals in their respective zones, right through the gigantic movements that have brought about the inversion. The evidences in Sikkim support the presence of such inver-

sions, an aspect, which as you are all aware, is a point of contention in the geology of the Scottish Highland. The mechanics of such gigantic inversions which permit the retention of the metamorphic minerals appears to be only imperfectly understood at present and deserves greater attention.

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SECTION OF BOTANY

President :—PROF. M. SAYEEDUDDIN, B.Sc., M.A. (Edin.),
F.R.M.S., F.L.S., F.B.S.

PRESIDENTIAL ADDRESS

SYSTEMATIC BOTANY AND ITS MODERN TRENDS

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1. INTRODUCTION

I wish, first of all, to offer my sincere thanks to the Sectional Committee and the Executive Committee of the Indian Science Congress Association for the great honour they have done me in electing me to preside over the Botany Section this year, and in so doing, they have honoured a very much neglected branch of Botany, namely, Systematics or Taxonomy which makes me and my colleagues in this field feel particularly privileged. It is a very happy coincidence that I should preside over the Botany Section at the place where I learnt my first lessons in Botany in the Intermediate class. Later, as a pupil of the late Fr. E. Blatter and D'Almeida of Bombay and Sir William Wright Smith of the University of Edinburgh, I got interested in systematic botany which I have pursued for the last 30 years. I am conscious of my shortcomings, but I can assure you that you will not find me lacking in enthusiasm, zeal and efforts in furthering the cause of such an important branch of botany as taxonomy, and I look forward to your help and cooperation in my task.

Thirteen years ago, Dr. K. Biswas (1943) in his Presidential Address to the Botany Section of the Indian Science Congress Association reviewed exhaustively not only the work on angiosperms but on other groups of plants also. Some of my other predecessors in this office have spoken on allied subjects (Champion, 1937 ; Bor, 1948 ; and Randhawa, 1949). I do not wish to tread the same ground. Confining myself mostly to angiosperms, I shall try to deal with my topic from a different angle altogether in the light of my experience both as a teacher and a research worker, and the recent developments in connection with the various

approaches to the solution of taxonomical problems. Owing to restrictions in the length of the address, I am sorry to have left out palaeobotany, ecology, and plant-geography which have played and are still playing an important role in systematic botany. For the same reason I had to omit the bibliography also. That the subject of Systematics has again gained its due importance is also indicated by the fact that the topic of my Address has been selected quite independently for discussion during this Session. The election of a systematist to the presidentship of the Botany Section this year is very opportune in view of the fact that the Government of India have realised the necessity of taking steps in this direction and have appointed an eminent botanist, Fr. H. Santapau, as Chief Botanist in order to organise and encourage researches on the floras of the various parts of our vast country. His is a great responsibility and we have great expectations from him.

Owing to an unfortunate tendency in the past to under-rate taxonomical work, the world in general and India in particular is now short of systematists to a dangerous extent. At last, this realisation has come, and I hope every effort will be made to make up for the lost time. Another important reason for this paucity is the difficulty for most of our university teachers to under take taxonomical work with sufficient enthusiasm, when our universities grudge the provision of sufficient grants for field excursions and other facilities, and on the contrary, consider excursions as only a holiday and picnic for the teachers and the taught. I am glad to remark that this tendency on the part of our universities is fast disappearing, and a better situation is obtaining in many universities. I do not agree with Biswas (1943) that as necessary facilities do not exist in the universities to carry on systematic and taxonomical researches, this should be tackled by the Botanical Survey of India. On the other hand, I believe that teachers of systematic botany in our universities should be persons who are actively engaged in systematic researches if we want the teaching of this branch of botany to achieve the desired standard, and the Survey can come to the rescue of such workers in providing them with necessary grants and facilities. Research in any branch of botany cannot be divorced from teaching. There is ample scope for both the Survey and the universities to carry on researches in this line.

The paucity of teachers in systematic botany in our country is deplorable. If we cast a cursory glance over our universities and research institutions, we will not find many persons whom we can class under Systematic Botanists of some repute. Among these few, mention may be made of S. P. Agharkar (on the vegetation of Khasi Hills, Bengal Flora, etc.), Fr. H. Santapau (on the flora of Bombay Presidency, etc.), T. S. Sabnis (on the flora of Sind and Punjab plains, etc.), J. F. Dastoor (on the useful plants of India and Pakistan), R. R. Stewart (on the flora of Masoori and Kashmir), M. Sayeeduddin (on the flora of Hyderabad), S. K. Pillai (on the flora of Annamalaiagar), G. D. Srivastava (on the flora of Allahabad), J. Venkateswarlu (on the flora and plant resources of the Andhra area), B. A. Razi, H. C. Govindu and C. S. Venkatesh (on the flora of Mysore), B. A. Razi (on the phytogeography of Mysore hill-tops), M. R. Rao (on flowering plants of Travancore), M. A. C. Ezekiel (Botanical features of Mahabaleshwar, etc.), R. Misra (the vegetation of the Rajghat Ravines), G. A. Kapadia (on Junagadh Plants, etc.), H. L. Chakravarty (on Calcutta Plants) from the universities.

Mention may be made of P. Maheshwari (on some plants of Eastern Rajputana and Upper Gangetic Plain), A. C. Joshi (Lahore District flora, etc.), T. S. Mahabale (on some ecological features of the vegetation at

Mt. Abu), M. J. Thirumalachar (Flora of Nandi Hills), M. R. Suxena (Grasses of Hyderabad), M. Abdus Salam (Hyderabad plants in general), who are a loss to systematics by having diverted themselves into other branches of botany. From amongst the systematists working in Research Institutes, etc., mention may be made of K. Biswas who has published a number of papers on many topics on the Flora of India and Burma, S. K. Mukherji (on the Labiatae of the Indian Empire, etc.), M. B. Raizada (on the plants of Upper Gangetic Plains, Chitagong, Orissa, etc.), D. Chatterji (Endemic Flora of India, etc.), C. McCann (on the plants of the Bombay Presidency, etc.), H. F. Mooney (on the plants of Behar and Orissa, etc.), V. Narayan Swami (on Orchids, Grasses, etc.), G. S. Puri (on Forest Ecology, etc.), B. L. Gupta (on the forest flora of Chakrata, Dehra Dun, etc.), and S. N. C. Iyer (on Fodder yielding trees in Madras Presidency). I have not mentioned the names of two eminent foresters, Drs. N. L. Bor and H. G. Champion who are now in Royal Botanical Gardens, Kew, and Oxford University, respectively. Of those medical men who have made valuable contributions to medicinal plants, I mention the names of Drs. K. R. Kirtikar, B. D. Basu and Lt.-Col. Dr. R. N. Chopra. I wish to be pardoned for any omissions.

Lack of encouragement has resulted in the systematists not taking sufficient pains to produce suitable regional floras. The result again is ignorance on the part of not only our students but the majority of our teachers about the most common plants in their region. Amongst other causes of our backwardness are the absence of Botanical Gardens, Herbaria and Museums. Joshi (1949) rightly laid great stress on the need of stimulating interest in systematic botany.

2. IMPORTANCE OF SYSTEMATIC BOTANY

Systematic botany aims at the arrangement of plants in a system, whether natural or artificial, mainly as a result of the study of external morphology and affinities, and in naming them according to the International Rules of Nomenclature. It is an important branch of botany with which even a layman is familiar, as the popular conception of botany is that it consists in collecting, naming and describing plants with the use of a complicated terminology. This makes it all the more difficult for a systematic botanist who is dealing specially with flowering plants, as he is expected to know and name all the plants around him. This expectation of laymen is to a great extent justifiable, for, of what value is a botanist who does not acquaint himself, first and foremost, with the plants surrounding him atleast to a reasonable extent. He may pursue any other branch of botany later on according to his liking, but as we are aware, the majority of our teachers and students show great ignorance about the most common plants of their region. Joshi (1949) hinted at this ignorance and quoted a friendly Englishman's remarks, "In India, people become botanists without knowing plants." As is rightly stressed upon by Merrill (1946), "taxonomy and the accurate identification of plants is basic to a proper understanding of myriads of problems in the general field of economic botany, pharmacology, agriculture, plant breeding, plant pathology, genetics, forestry, morphology, physiology and many other fields into which plant science or botany *sensu latiore* has been sub-divided". Not only this, their development would have been impossible and as Turrill (1940) remarks "It is becoming more and more obvious that recent discoveries in cytology, ecology and genetics have often a bearing on taxonomy. Daring the reproaches of his biological colleagues, the taxo-

nomist maintains that his subject is the alpha and has the potentialities of becoming the omega of a very considerable part atleast of biological knowledge."

Puri and Misra (1955) realising the importance of this branch of botany have stated that "the most natural method of teaching botany to Indian students would probably be to start with systematic botany and plant geography for the first year class after a short field course in morphology."

Importance of Correct Identification

Needless to remark that we cannot proceed with any type of work on a plant unless it is correctly identified. Merrill (1946) relates the horrible classical example of the disastrous results produced by a research student working on a mis-identified material. We in India are also aware of the common mis-leading horticultural names, for example, the "Croton of gardeners" has nothing to do with the genus *Croton*; on the contrary, it belongs to the genus *Codiaeum*. What is commonly called the Weeping Willow by gardeners is not *Salix*, but *Schinus molle* of the family Anacardiaceae. What is grouped amongst the palms is not a palm at all, but *Carludovica* of the Cyclanthaceae, and what are called cactii need not all belong to the family Cactaceae, but they may consist of plants belonging to such un-related families as Crassulaceae, Vitaceae, Compositae, Asclepiadaceae, Euphorbiaceae, etc. Examples can be multiplied.

Economic Aspects of the Study of Systematic Botany

There are thousands of species of plants of economic importance whether used for food, for medicine, or in various industries, for example, wood, paper and pulp, tanning, dyeing, oils and perfumes, fibres, gums and resins, latex, etc. The special properties of such plants were in the past discovered by observation and experience rather than by deliberate investigation. Now the case is different. If one species of *Ephedra* yields ephedrine and one species of *Taraktogenos* or *Hydnocarpus* yields Chaulmoogra oil and some species of *Cinchona* yield quinine, it is quite probable that other species of the same genera may yield the same or similar products. Before the War, Europe and America depended on Asia and Malaysia for their supply of rubber, quinine and various other products. During the war, they were compelled to find substitutes, as we did to a certain extent in India. Finally I will quote Merrill (1946) who rightly remarks, "it is in this specialised field of potential substitute plants that may yield important products that we now lack, that the trained and experienced workers can render, and are rendering, fundamental basic services. It is this type of individual who knows his plants and who knows plant relationships who can serve to great advantage, for his accumulated store of special knowledge cannot be matched by those botanists trained and experienced in other fields remote from that of taxonomy and systematic botany."

3. ROLE OF ANATOMY IN TAXONOMY

(a) *Vegetative*: The application of anatomical data as an aid in classification is not new. Besides their use in delimiting species, genera and families, anatomical investigations have helped to solve some important systematic problems concerning affinities and relationships. To be brief

I am not quoting any examples from the old literature. Mention may now be made of the more recent schools of thought and the important contributions of Solereder (1908) in Germany, Bailey (1941, 1953) and his colleagues and students in U.S.A., and by Chalk (1937, 1950) and Metcalfe (1950, 1953, 1954) in Great Britain. In their investigations on the Winteraceae, Bailey and his associates have shown that this family is of general ranalian affinities, as evidenced by the secretory cells and other characters, but it does not appear to be closely related to any specific surviving family of the ranalian complex. According to Bailey, Winteraceae are particularly significant in the study of the comparative morphology and phylogeny of the dicotyledons not only because of their retaining a primitive vessel-less xylem but also because of their floral characters, which I shall deal with under the next sub-heading.

Money, Bailey and Swamy (1950) have studied the morphology and relationships of the Monimiaceae. The investigations of the vessel-less genus *Amborella* and of *Austrebaileya* (Bailey and Swamy) have strengthened their opinion that the Monimiaceae is a key family in understanding and interpreting the morphology of the Lauraceae, Gomortegaceae, Hernandiaceae, and Chloranthaceae and probably other dicotyledonous families. On the basis of anatomical and morphological evidence, they have shown that *Idenburgia* and *Scyphostegia* do not belong to the Monimiaceae, nor is there evidence of their close relationship to this family.

Bailey (1944, 1949) has shown that vessels have originated independently in Selaginellales, Filicales, Gnetales, monocotyledoneae and the dicotyledoneae. Cheadle (1953) in amplifying certain of the evidences regarding the independent origin of the vessels in the monocotyledoneae and dicotyledoneae, comes to the conclusion that vessels arose in dicotyledons probably several times and that assuming a monophyletic origin for angiosperms as a whole, and for the monocotyledons, vessels originated and specialised independently in the monocotyledons and dicotyledons.

Chalk (1937) investigated the anatomy of the woods of 1272 genera of dicotyledons to ascertain their phylogenetic value. He came to the conclusion that the parallelism between wood anatomy and taxonomy tends to disappear in the taxonomic groups above the family level. He used the evidence of the degree of specialization in the wood to compare the sequence adopted in the systems of Bentham and Hooker, Engler and Hutchinson, and found that Hutchinson's arrangement of the Archichlamydeae agrees more closely than that of Engler, that the Monochlamydeae of Bentham and Hooker appears to be slightly less specialized than Polypetalae, but neither group differs very markedly from the average for all the dicotyledons examined. The Metachlamydeae (sympetalae) includes a mixture of specialized and un-specialized woods which can be separated by the type of parenchyma present. He further concludes that the woods of Engler's Primulales, Plumbaginales, Contortae (part), Tubiflorae, and Campanulatae possess paratracheal parenchyma and constitute a very highly specialized group.

Metcalfe (1954) and Metcalfe and Chalk (1950) believe that while the anatomical methods are likely to prove valuable concerning angiosperm phylogeny and taxonomy, their value in determining the limits of species and taxa of lower rank, seems likely to be less fruitful. The taxonomical value of anatomical characters is inversely proportional to their plasticity. As to be expected, those which are particularly liable to become modified in response to ecological changes are most unsatisfactory. Plants belonging to different and not closely related families sometimes develop similar character as a result of a common dry habitat, for example, Euphorbiaceae,

Cactaceae, Geraniaceae, Compositae, Apocynaceae, Asclepiadaceae, etc. Although the xerophytic characters exhibited by these families possess diagnostic value, they are not by themselves to be taken as evidence of taxonomic affinity between the plants possessing them. Although no characters are strictly immutable, the systematic anatomist must rely on characters which are less plastic. In his recent contribution (1954), Metcalfe rightly emphasizes the fact that "as endomorphic criteria are not always of equal value in all families and anatomical work is necessarily slow, it is desirable to concentrate on (a) families that present taxonomical difficulties, e.g. Sapotaceae, Euphorbiaceae or Gramineae; (b) families that are specially interesting from the phylogenetic standpoint; (c) families of succulent plants, such as, Crassulaceae or Aizoaceae; (d) families that are taxonomically heterogeneous; (e) families that include species that are of actual or potential economic importance."

Fahn (1954) has worked out the anatomy of all the species of the 8 genera of Xanthorrhoeaceae and comparing his data with those obtained by Cheadle (1942) he has come to the conclusion that the Xanthorrhoeaceae resemble most closely the Agavaceae.

Amongst others who have done some anatomical work in India, mention may be made of Sabnis and Mullan (Bombay), Majumdar and Chakravarty (Calcutta), B. G. L. Swamy (Madras), Sayeeduddin (Hyderabad), Maheshwari (Delhi), Joshi (East Punjab) and their colleagues and students. The last two have become a loss to anatomy, having taken up embryology. Chowdhury (Dehra Dun) has done good work on wood anatomy. Sahni, Kaul, Mahabale, Surange and others have worked on the anatomy of living palms in connection with their studies in fossil palms (Palmoxyla). Mahabale has also been able to recognise a species of fossil *Sparogonium* from Tertiaries of India mainly with the help of anatomy.

A few fresh examples may be cited of the genera which have been transferred from some families to others or have been placed in independent families as a result of anatomical investigations. Airy Shaw, from an examination of the external characters of the genus *Dioncophyllum*, found that it was out of place in the family Flacourtiaceae. His subsequent work and the anatomical investigation of Metcalfe led to the establishment of a new family, the Dioncophyllaceae, which does not appear to have any close allies but has slight resemblance to Nepenthaceae and Droseraceae. A new family was established by Brenan of Kew (quoted from Metcalfe, 1954) for a new species, *Medusandra richardsiana*, for which Metcalfe found considerable anatomical support. Establishment of independent families for the relic genera like *Trochodendron*, *Drimys*, *Zygogynum*, *Illicium*, *Schizandra*, *Kadsura*, *Tetracentron*, *Euptelea*, *Cercidiphyllum*, *Amborella*, *Trimenia*, and many others is justifiable as has been done in the case of *Casuarina*, *Leitneria*, *Myzodendron*, *Lactoris*, etc. (Bailey, 1953).

(b) *Floral Anatomy*.—Floral anatomy consists in studying the course and distribution of vascular bundles within the receptacle and floral organs and it has also its share in taxonomical and phylogenetic studies, as anatomical characters of the flower have proved helpful in limiting genera and species. Floral organs being more conservative than vegetative ones, data from anatomical studies of the floral organs are fairly reliable and render valuable service to the systematists. Puri (1952), however, states that the doctrine of conservatism of the vascular bundles has been proved to be un-sound and is no longer tenable. Saunders (1939) makes a strong plea for closer co-operation between systematic botanists and the morphologists in order to facilitate the solution of problems common to both, after citing a number of examples to show that many structures are not

what they appear to be and have till now been taken to be. The terminology used by the systematists has served his practical needs, but with our grown knowledge today it is to some extent out of harmony with reality. "The contentment", she says, "has dulled the perception to look beyond, resulting in often obscuring the trend of evolution and the inter-relationship between allied forms". She cites several species belonging to the genera *Cistus*, *Hypericum* and *Veronica* as examples of fusion between, or non-segmentation of, some but not all of the floral members of one and the same whorl. Two instructive examples of *Saraca* (Caesalpinoideae) and *Soldanella* (Primulaceae) are given to show the occurrence of concrescence of a more complex nature when more than one whorl is involved. Finally, she cites the example of androecium in Cucurbitaceae. All these examples show us how one can remain in the dark by inspection of the outward form and how internal anatomy gives the clue to the proper understanding of such intricate problems.

Eames (1953) has dealt with this aspect in some detail with regard to generic limitation, and I repeat here some of his observations. The external characters, whether they be vegetative or floral, are bound to vary much more than internal ones and, therefore, the latter are sometimes more valuable than the former. The lost organs are not seen externally but their vascular supply frequently persists. It is these hidden vascular vestiges which give the clue to the ancestral position of surviving ovules and may serve as an important generic or family character, and the type of ancestral placentation may determine family and order of relationship. Although our knowledge of the floral anatomy of all families of angiosperms is very meagre, we know the more important characters bearing on relationships because of our fairly advanced knowledge of stem anatomy, and as we know, anatomically a flower is but a leafy stem. But in dealing with internal as with external characters, one has to bear in mind that many of these characters may have developed under parallel or convergent evolution, and what characters are important in one genus or family may not be so in others.

In floral anatomy, not only are the family and generic characters well marked, even specific characters may be so, as in *Vaccinium* and *Boerhaavia*. The two species of *Boerhaavia* can be easily distinguished from one another by the presence (*B. repanda*) or absence (*B. diffusa*) of marginal bundles in the perianth segments (Puri, 1952). Examples of the use of anatomy in generic limitation are found in the family Ericaceae where the position of the ovary (superior or inferior) and the extent of fusion of vascular supply of the floral organs are of little significance as generic characters.

Important examples of the correlation of floral anatomy and the anatomy of secondary wood are found in the vessel-less dicotyledons, in the Juglandaceae and other Amentiferae, Caprifoliaceae (*Sambucus* which on this basis does not belong in this family), and Ranunculaceae--the removal of *Paeonia* and formation of a new family Paeoniaceae which is also supported by the general anatomy of the vegetative body and by embryology (Kumazawa, 1938). Eames states that the nature of the vascular supply to the stamens alone is sufficient to remove *Paeonia* from the Ranunculaceae. Separation of *Ranunculus* (included in Anemoneae by Prantl) into a separate tribe Ranunculeae on the basis of vascular supply of the carpel and that of the ovule is also significant.

Bailey and Nast (1945) after a detailed and thorough morphological study of Magnoliaceae have re-arranged its genera under several distinct families. Thus *Drimys* is placed along with five other genera, *Bubbia*,

Belliolum, *Pseudowintera*, *Exospermum* and *Zygogynum* in a separate family, Winteraceae. Not only do they differ from the Magnoliaceae (*sensu restrictus*) in wood anatomy, etc., they differ from it in important morphological characters of the floral organs. Some more examples of the correlation of vegetative and floral anatomy are found in the creation of distinct families for *Himantandra*, (Himantandraceae), *Degeneria* (Degeneriaceae), *Magnolia* (*Liriodendron*), etc., (Magnoliaceae, *sensu restrictus*), *Trochodendron* and *Tetracentron* (Trochodendraceae), and *Schizandra* and *Illicium* (Schizandraceae), (Bailey, Nast and Swamy, 1945, 1949).

Study of floral anatomy of Amentiferae and allied families has shown that they comprise a heterogeneous assemblage, that the various families are more or less specialized and that their apparently simple structure is a result of reduction. Furthermore, such studies in Papaveraceae, Capparidaceae, Cruciferae and Moringaceae have led to the conclusion that their gynaecium make-up is essentially on the same plan. It has been suggested that the parietal placentation in these families has been derived from axile placentation, and that somehow the original inverse orientation of the placental strands is retained. If this is so, then the inclusion of the doubtful Moringaceae in the *Rhoeadales* is strengthened. Both Passifloraceae and Cucurbitaceae are reported to possess these peculiarities, (Puri, 1947, 1952 A.), thus supporting the affinities suggested between Moringaceae and Passifloraceae. According to Dickson (1935, quoted from Puri, 1952) Papaveraceae seem to be directly connected with the Ranunculaceae through *Platystemon*.

On the basis of the vascular anatomy of the flower in many members of the Santalaceae and Olacaceae, it is shown that the two families are most closely related (Smith and Smith, 1942). The work on Boraginaceae and Solanaceae confirms the taxonomic treatment of the sub-families and tribes. Subrahmanyam (1955) after a morphological study of some species of *Sedum* has come to the conclusion that the change of the name *Rosularia pallida* to *Sedum chrysanthum* (Boissier) Raymond-Hamlet on certain taxonomic characters is justified.

There is a great dearth of floral anatomists in India. I have already quoted Puri in several places and further reference may be made to his work in Parietales (1939), and Raghavan's work on Capparidaceae (1939).

(c) *Palynology*.—The use of pollen characters in systematic studies in angiosperms is again not new. As far back as the middle of the 17th century, pollen grains were described by Grew and Malpighi as "Globes" and "Globulets" for the first time. There was no contribution of note until 19th century. Then the works of Mirbel, Von-Mohl, Purkinji and others appeared. Amongst the more recent workers may be mentioned the names of Hermann Schacht, Nageli, Rasanaff, Fischer and M. P. Edgerworth. Kerner and Oliver (1897) have given a brief but very informative account of some of the pollen forms. Pope (1925) has also worked on pollen morphology. Now, Wodehouse and Erdtman and their colleagues and pupils are amongst the few enthusiastic workers in this field. On going through the literature of Palynology (Erdtman, 1935, 1953, 1954), it is noticed that India is lagging very much behind other countries in this important line of enquiry. Some of the few contributions from India which deal exclusively with studies in the pollen grains in the angiosperms are by Erlanson (1934), Sayeeduddin and his associates (1942), C. V. Rao (1950) and Sampath (1951), etc. Of course, many of the contributions by embryologists like P. Maheshwari, A. C. Joshi, B. M. Johri, J. Venkateswarlu, T. S. Raghavan, V. Puri, S. B. Kausik, K. I. Subrahmanyam, L. B. Kajale, B. Singh, B. A. Razi, their pupils and others (we have

quite a number of embryologists in our country) contain some descriptions of pollen. Mehra (1938) and others have worked on the pollen grains in gymnosperms. While there can be no doubt as to the usefulness of palynological data in taxonomic conclusions when supported by facts obtained from anatomical, cytological, embryological and other studies, it is not yet safe nor possible to be guided merely by such data for the many taxonomical indications which they provide, for example, pollen grains of more or less the same type sometimes occur in plants which are supposed to be not closely related, and more than one pollen type may be found in certain genera and, furthermore, several types of pollen grains may be produced by a single species (Erdtman, 1952; Sayeeduddin and his associates, 1942).

A number of examples can be quoted to show how the study of pollen morphology has been helpful in taxonomy. This study led Erdtman to place the genus *Kania* (Saxifragaceae) and the genus *Thorelia* (Lythraceae) in the family Myrtaceae which was endorsed by the anatomical work of Metcalfe (1954). I will draw freely on Prof. Erdtman's recent contribution in this regard (1954). Palynological evidence in conformity with other approaches does not support a sharp demarcation between monocotyledons and dicotyledons, as monocotyledonoid characters occur in dicotyledonous families like the Anonaceae, Calycanthaceae, Canellaceae, Chloranthaceae, Degeneriaceae, Eupomatiaceae, Himatan-draceae, Magnoliaceae, Monimiaceae, Myristicaceae, Nymphaeaceae, Piperaceae, Saururaceae, etc. On the other hand, some monocotyledonous families exhibit certain dicotyledonoid characters. Typical dicotyledons possess pollen grains with composite apertures. The apertures of the pollen grains of the monocotyledons and the monocotyledonoid dicotyledons seem to be more primitive than the apertures of the pollen grains of many dicotyledons.

One of the reasons for making a separate small family Gyrostemonaceae as distinguished from Phytolaccaceae is their thick-walled pollen grains which have no counter part in other plants. According to Kumazawa (1938), the berberidaceous genera of Engler's system, except *Nandina*, *Podophyllum* and *Diphylleia* should be grouped together under two sub-families, Berberidoideae and Epimedioideae (not under two tribes, Berberideae and Epimediaceae as in Engler's system), the most striking differences between the two sub-families being found in the structure of the pollen grains.

Dahl (1952) has made a detailed study of pollen in the family Icacinaceae, and has devised a system of genera on the basis of certain trends of pollen specialization which he has compared with the one devised independently by Bailey and Howard (1941) for the same family on anatomical grounds. He has found that the majority of the species having the least specialized pollen grains belong to the least advanced anatomical group, while most of the species possessing specialized pollen grains are anatomically the most specialized. He concludes by saying that "the unusual degree of association between the pollen and the anatomical spectra in this family, made up of approximately 300 species distributed amongst 60 genera, is indicative of the significance of intensive morphological studies of pollen in ultimately phylogenetic problems."

The presence of crotonoid pollen grains in Callitrichaceae strengthens the old assumption of its relationship with the Euphorbiaceae. Several buxaceous genera and the Thymelaeaceae also possess such pollen grains. Several genera of the Saxifragaceae can be removed from it on the basis of palynological data. Typical campanulaceous pollen grains were found in

the flower fragments of *Berenice arguta*, and a reinvestigation of other features of this plant supported its reference to the Campanulaceae. Pollen-morphological data justify the splitting up of Magnoliaceae and Olacaceae into smaller units.

These are but few examples to show the importance of palynological research which if pursued continuously may help in solving many a controversial problem.

4. EMBRYOLOGY AS AN AID IN TAXONOMY

While the contributions of anatomy to taxonomy are very familiar to majority of us, those from embryology are less known and familiar. We, in India, are now stronger in embryology than perhaps in any other branch of angiospermic studies, thanks to some of the pioneer embryologists, like the late Professors W. Dudgeon and S. Sampathkumaran, Professors P. Maheshwari, A. C. Joshi, L. N. Rao, T. S. Raghavan, C. V. K. Iyengar and Dr. I. Banerji followed by Profs. J. Venkateswarlu, B. G. L. Swamy, V. Puri, B. M. Johri, B. Singh, K. N. Kausik and Drs. M. Anantaswami Rao, K. Subrahmanyam, L. B. Kajale, their associates and many others.

From the beginning of this century, embryology began to be applied to taxonomy in solving problems of affinity and relationships. The most important contributions in this field have been made from Sweden, Germany, U.S.A. and India. The value of embryology in systematic botany has been stressed upon amongst others by P. Maheshwari (1945, 1954). A few examples may be cited to show what part embryology has played in the determination of the proper position of some difficult families or in explaining their affinities. The family Empetraceae has been placed by some in the monochlamydeae and by others in the Sapindales or Celastrales. Samuelsson (1953, quoted from P. Maheshwari, 1945) has definitely shown on embryological grounds that its proper place is in the order Bicornes under the Ericales. Lennoaceae was placed by Solms-Laubach in the Ericales, followed by Hutchinson (1926). Engler and Gilg (1924) assigned it to the Tubiflorae, near Boraginaceae. Anatomical and morphological study of *Lennea* and recently of *Pholisma* by Copeland has supported its position in the Tubiflorae as a separate sub-order occupying a primitive position.

Take the example of Cactaceae, which is unsurpassed in its variety, and therefore, has given much scope for differences of opinion amongst experts. Wettstein places it in Centrospermae; Engler and Diels in a separate order Opuntiales near Passifloraceae; Warming in Cactales following the Centrospermales and Hutchinson in the same order but next to the Cucurbitales. Mauritson and Neumann's work and recent evidence shows that Cactaceae belong to the Centrospermales and is entirely in favour of regarding it as a sort of bridge between Aizoaceae and Portulacaceae. Buxbaum is also of the opinion that the Cactaceae are allied to the Aizoaceae and should be placed in the Centrospermales.

Garryaceae has been placed by Engler and Diels (1936) amongst the most primitive dicotyledons. Bentham and Hooker (1880) have placed it in the Archichlamydeae near Cornaceae. Hallock (1930, quoted from Maheshwari, 1950) on morphological and embryological grounds concludes that the Garryaceae are not primitive but must be considered as the highest of the Umbelliflorae immediately preceding the Sympetalae. According to her, the dioeciousness of *Garrya* may be a derived rather than a primitive character. Maheshwari remarks that the rudimentary haustorial structures observed by her at both ends of the endosperm and which she considers

to be derived from the synergids and antipodal cells very likely originate from the micropylar and chalazal cells of the endosperm. He further adds that if this interpretation is found to be correct, it would be a very strong argument in favour of the advanced position of the Garryaceae.

Onagraceae is considered to afford one of the best examples of the value of embryology in taxonomy. A typical monosporic 4-nucleate embryo-sac consisting of an egg-apparatus and single polar nucleus occurs in every genus and species except in *Trapa*. This embryologically does not belong in the family Onagraceae, and its separation as a family Trapaceae is justified. Joshi and Venkateswarlu (1935, 1936) have added to the arguments of Tischler and Mauritson "that the embryo-sac of the Lythraceae forms phylogenetically an intermediate stage between the 4-nucleate embryo-sac of the Onagraceae and the normal 8-nucleate embryo-sac", by showing that the various stages in the reduction of the antipodal nuclei in *Lawsonia inermis* form a still stronger connecting link.

Joshi and Rao (1936) comparing the embryological features of Phytolaccaceae, Aizoaceae and *Gisekia* have come to the conclusion that the family Aizoaceae (Ficoideae of Bentham and Hooker) may be split up into two families Molluginaceae and Ficoidaceae, as Hutchinson has done, and that *Gisekia* be placed in the Molluginaceae. Bhargava has worked out the life history of *Trianthema monogyna* Libb. and states that Aizoaceae has departed least from Phytolaccaceae which is regarded as the parent family from which other families included in the order Centrospermales have originated.

The doubtful position of the Callitrichaceae has been cleared by the work of Jorgensen. The occurrence of tenuinucleate ovule with a single massive integument and the cellular angiosperm forming well-developed haustoria and features characteristic of the Tubiflorae and suggest a closer relationship of Callitrichaceae with the Labiatae or Verbenaceae than with any of the families to which it was considered to be related in the past. Any way, its present assignment to the Geraniales is highly objectionable.

Kajale (1940) working on *Sesuvium Portulacastrum* Linn. has supported the conclusions of Joshi and Rao (1936) that the genus *Sesuvium* (placed in Ficoidaceae by Hutchinson) closely agrees with the genera *Trianthema*, *Mesembrianthemum* and *Tetragonia*.

Krishna Iyengar's (1942) investigation on *Tetranema* and *Verbascum* shows that there is much in common between them, and that the chalazal haustorium of *Tetranema* is likely to throw some light on the evolutionary tendencies of the organ. "The frequent occurrence of a uni- or bi-nucleate haustorium indicates its affinity to *Vandellia*, while the occurrence of a tetra-nucleate body indicates its transitional position between *Verbascum* with 4 uni-nucleate haustoria and the other members with a single bi- or uni-nucleate haustorium." From the work on *Torenia cordifolia* and *T. hirsuta*, he comes to the conclusion that *Torenia* shows many points of resemblance with *Vandellia*, *Limosella* and other genera of the family.

Venkateswarlu's studies in the Thymelaeaceae (1945, 1947) support a relationship of the Thymelaeaceae with Geissolomataceae and Penaeaceae on the one hand and with Combretaceae on the other. They also favour the removal of Nyctaginaceae from the Centrospermales and grouping it with Thymelaeaceae, Geissolomataceae and Penaeaceae as proposed by Hutchinson (1926). His work on the Sonneratiaceae has shown that their embryological features show no difference from those of the Lythraceae. Murty's studies in the order Parietales (1954) lend support to the view that Tamaricaceae is not related to Salicaceae.

Nirmal Narang (1953) is of the opinion that, on embryological grounds, the family Stackhousiaceae is more properly assigned to the Celastrineae than near the families Scrophulariaceae, Selaginaceae or Lobeliaceae, thus justifying the position assigned to Stackhousiaceae by Engler.

The work of Schnarf, Stenar, Cave (1953) and others has changed our ideas regarding the inter-relationships of the sub-families and tribes of the Liliaceae. It has been shown that a close relationship exists between *Asphodelinae* and *Aloineae*, and that the gulf between the sub-tribes *Asphodelinae* and *Anthericinae* is sufficiently wide to justify their separation into at least different tribes or even perhaps different sub-families.

The following points emerge from Subrahmanyam's work (1955) on sedums. The change of name *Rosularia pallida* to *Sedum chrysanthum* (Boissier) Raymond-Hamlet is also justified on embryological grounds, that Crassulaceae resembles Saxifragaceae in a number of embryological characters and that the latter are more advanced than the former. Podostemaceae differs strongly from the Crassulaceae. It is significant to find that the Crassulaceae and Saxifragaceae have a number of embryological features in common with the different families of the Ranales, pointing towards a possible origin of Rosales, thus supporting Bessey and Hutchinson.

5. ROLE OF CYTO-GENETICS IN TAXONOMY

Experimental methods are attaining greater and greater importance as they are helpful in studying inherent relationships upon which ultimately may be based a natural classification. Since a quarter of a century or so, cyto-genetical data are being applied to taxonomic problems. "Chromosomes are not another character comparable with the superficial characters of organisms. The chromosomes determine the character, the characters do not determine the chromosomes. Changes in the chromosomes determine the isolation and divergent evolution of races, ecotypes, species and families." (Darlington, 1950). Therefore, the generic structure of plants is throwing new light on the status of taxonomic groups and is indicating how futile it is to attempt all-inclusive definitions of species. Chromosome number and chromosome morphology have become specific characters of some taxonomic value and are helpful in the elucidation of certain phylogenetic problems (Goodspeed, 1950).

Taxonomy is based on the recognition of inherited phenotypic differences. "In speciation", according to Gates (1950), "there are two main streams of change (a) gene mutations which alter phenotype, (b) chromosome changes, such as translocations, which alter gene linkages and introduce intersterility. Both types of changes are subject to natural selection, and individuals heterozygous for a translocation may show more vigour in certain conditions. A species has a dynamic system consisting of successive populations of individuals. Much evolution, but by no means all, has occurred at the diploid level." Intersterility, Gates states, can arise at any stage in the process of speciation. In a discussion of sub-specific units, he cites the work of Clausen, Keck (1950) and Hiesey, with ecotypes transplant experiments in the genera *Achillea* and *Potentilla*; also the nature of the species in *Antirrhinum*, *Silene*, *Platanus*, *Crepis*, *Zauschneria*, *Balsamorhiza*, *Catalpa*, *Quercus*, *Pinus*, *Parthenium*, *Solidago*, *Lactuca* and other genera.

Rollins (1953) refers to investigation of Balcock and Stebbins (1937) on the *Crepidinae* and Clausen and Keck also on the *Madinac*, but remarks that they are "as yet too incomplete and too restricted to permit effective

generalization". On the basis of generic evidence Reeves and Mangelsdorf (1942, quoted from Rollins, 1953) have transferred *Euchlaena mexicana* to the genus *Zea*. While the cases of *Madia nutens*, *Layia* and *Euchlaena mexicana* serve as classical examples of the use of genetic evidence in settling the generic disposition of a single taxon, it is hoped that more and more investigations of this type will solve broader problems involving many species and more genera.

Rick's work on the hybrids between *Lycopersicum esculentum* and *Solanum Lycopersicoides* has revealed a close relationship between the genera *Lycopersicum* and *Solanum*.

Sakisaka (1950) has shown that remarkable dissimilarities of habits occur between plants with a small number of chromosomes and those with a large number of chromosomes. Herbs with a small number of chromosomes are annuals, while those with larger number of chromosomes are perennials. The two groups of plants differ from each other in fertility, activity, adaptability, rate of growth and hybridity. There is a gradual dominance of vegetative propagation over seed propagation from diploid to polyploid plants in the same genus.

Valentine (1950) working on *Primula* and *Viola* concluded that the extent to which compatibility and hybrid fertility can be used as taxonomic criteria may vary with the breeding system of the group under investigation. Lamprecht's (1950) study of the species cross *Phaseolus vulgaris* $\times$ *Coccineus* and vice versa has shown how a single gene can cause an insurmountable barrier between two species. Therefore, he believes that taxonomic studies on a gene-analytical basis seem to be of the greatest interest. The general uniformity in the chromosome number in the genera of the Leguminosae is very valuable in determining the proper classification.

Baldwin and Speese (1955) working on Alismataceae have shown that the idiogram for the taxon of *Lophotocarpus* differs from that of *Sagittaria*, and that this evidence is important in keeping this plant generically separate.

The most interesting general principle arising from the study of chromosome numbers in the flowering plants is the one which relates to stability of chromosome numbers in groups of species with the longevity of the plants concerned. Thus the woody flowering plants retain a conservative chromosome structure which reflects their phylogeny. By her study of the magnolias (Diploid - $2n=38$) Janaki Ammal (1952) has shown that there is "indirect cytological evidence that the living habits of plants that grew in Greenland and South America and Europe as far back as 100 million years are still found cytologically unchanged in the flora of S.E. Asia. On the other hand, it is not possible to trace annual and herbaceous plants like *Crocus*, *Crepis*, *Ranunculus*, etc. even to a common chromosome origin for each genus. (Darlington, 1950).

Besides the cytological study of Indian cultivated plants, for example, rice, maize and millets, pulses, sugarcane, cotton and jute, by a number of cytologists in research institutes, departments of agriculture and universities, like B. P. Pal, Janaki Ammal, K. Ramiah, T. S. Raghavan, N. Parthasarathy, J. Venkateswarlu, K. V. Srinath, A. Abraham, S. P. Naithani, B. S. Kadam, G. S. Bhatia, K. Choudhari, N. K. Iyengar, K. T. Jacob, S. Sampath, S. L. Tandon and others, some cytological work on other plants also has been done in our universities by A. C. Joshi and his associates on Chenopodiaceae, Phytolaccaceae, Amarantaceae and Agavaceae; by T. S. Raghavan and his co-workers on spp. of *Scilla*, *Sesamum*, Bignoniaceae and Rubiaceae; by I. Banerji and his associates on some Zingiberaceae, Araceae, Pontederiaceae, Leguminosae and Cucurbitaceae;

by P. N. Bhaduri on solanaceous plants, cucurbits, etc. ; by J. Venkateswarlu on Thymelaeaceae, and maize relatives ; by J. J. Asana and R. N. Suttaria on *Carica* and *Luffa* and by others on several plants and families.

6. CONCLUSION

Ladies and Gentlemen,

I have tried to show as far as possible and briefly the importance of the study of systematic botany and also to what advantage the systematists can use the pertinent data from various allied branches of botany in the solution of their problems. The criticism which used to be levelled against systematists that they were not sensitive to new points of view and advances in allied fields is no more valid, although there was justification for it in the past. (Goodspeed, 1950 and Lawrence, 1953). The under-estimation of taxonomy and hence lack of facilities for such work led to the stagnation and lagging behind of this branch compared with newer branches, like cytology and genetics, etc., leading to the acute shortage of trained personnel in this field. Plant science, like other sciences, has undergone such rapid development that there is a great need for closer co-operation between experts in various fields of botany. To quote Prof. Bailey (1951), "we must now strive in botany, as in national affairs, to prevent a reversion to isolation and to intellectual encystment". As a matter of fact, we have to go beyond botany to take help from the data obtained in subjects like physics, chemistry and statistics. Although it is premature to foretell the results, chemical analyses of plant substances and serum analyses are expected to yield clues to relationships. All this shows the broadened scope of the new systematics.

Propaganda in favour of one line of research against others cannot take us far. There is no need for any antagonism between the pursuers of various branches of botany. Let us, therefore, cut the barriers and proceed with proper understanding and in close co-operation with one another. I am sure this will lead to mutual benefit and will go a long way in the progress of botany as well.

There is much scope for systematic researches in India. The Botanical Survey, Research Institutions and Universities all can play their part. Besides the need for a revision of the various floras including 'Hooker's *Flora of British India*' and 'Cooke's *Flora of the Presidency of Bombay*', there is a very pressing need for the preparation of regional floras. Fr. Santapau (1952) and Janaki Ammal (1954) have discussed these matters at some length and I endorse their views. Let us hope that the newly organised Botanical Survey of India will try its utmost to offer facilities to workers engaged in this field and thus revive the study of systematic botany in India and give it the status it deserves.

SECTION OF ZOOLOGY AND ENTOMOLOGY

President :—M. L. BHATIA, Ph.D., D.Sc., F.N.I., F.Z.S.

PRESIDENTIAL ADDRESS

ZOOLOGICAL TEACHING AND RESEARCH IN INDIA

INTRODUCTION

I thank you for the honour you have conferred upon me in electing me as President of this section. Fully conscious as I am of my limitations, I seek your indulgence in overlooking any obvious shortcomings in the presentation of my address.

In selecting a suitable subject, I had to choose between the usual custom followed on such occasions of either presenting an account of personal contributions in a particular field of Zoology on the one hand, or on the other to deal with a subject of general interest, as was done by some of my distinguished predecessors. I have preferred to follow the latter course, since I felt that the subject of my own field of study might have appealed only to a small section of the members attending the session. I have, therefore, decided to speak on certain general considerations relating to zoological teaching and research in India. I have thus taken the opportunity of expressing my views on a subject over which I have pondered for many years, and which is of special importance in connection with the future development of zoological studies in the country.

I have kept teaching and research together as I advocate most strongly the combination of the two. Unfortunately in India there has been a marked tendency towards a divorce between research and teaching which, in my opinion, is undesirable.

It is unfortunate that as compared with other sciences, Zoology has progressed the least in this country. Today's gathering of eminent zoologists of India provides an opportune moment for inquiring into the causes of this arrested progress of Zoology in our country. Further, in order to be able to make plans for the future it is essential to take stock of our achievements in the past, as also of deficiencies both in teaching and research work and the handicaps against which the Indian zoologists have had to perform their duties.

TEACHING OF ZOOLOGY

Panjab was one of the earliest to introduce the teaching of Zoology up to the University standard. It developed teaching and research in Zoology under the able guidance of the late Col. J. Stephenson. The fact that many of the important posts in the field of Zoology in India

are, even to-day, occupied by the products of the Panjab School of Zoology bears ample witness to the high standard of education that was imparted by the Zoology Department of that University. Teaching in Zoology was also introduced in the Universities of Calcutta, Madras, and Allahabad at about the same time as in the Panjab University. A very high standard of teaching was attained in Madras under the late Prof. K. Ramunni Menon and in Allahabad under the late Prof. A. D. Imms and Dr. W. N. Woodland. The example set by these universities was soon followed by those of Lucknow, Banaras, Aligarh and Mysore, and later Osmania, Andhra, Nagpur, Agra and Annamalai Universities introduced Zoology as a subject for post-graduate studies. To-day, out of 31 Universities in India as many as 21 claim to have post-graduate teaching and research facilities in Zoology.

It may perhaps be gratifying to realise that during the course of a few decades there has been a great multiplication in the number of Zoology teaching institutes. Large number of zoologists are trained by these institutes, but it is sad to note that the standard of the product of these Universities has to a great extent deteriorated as compared to the standard of teaching that was earlier attained by some of the Indian Universities. I have little doubt that those of you who have a long association with the teaching of Zoology in India would generally agree with this view. It goes without saying that no remedial measures in this respect are possible without a dispassionate inquiry into the causes that have led to this deterioration of the standard in the country.

It would not only be most unkind but unjust on my part to apportion blame entirely on those who are responsible for the teaching of Zoology. In fact, in this country there is no dearth of people who possess potential capabilities of developing into first-rate teachers, nor is there any lack of sincerity. But, under the present system of education, there are many factors which stand in the way of the production of really competent teachers in Zoology. Further, those zoologists who have devoted their lives to the teaching of the subject are, at present, seriously handicapped by circumstances beyond their control. It is, therefore, my considered opinion that the fault lies, not so much with the teacher, as with the system of education and various extraneous factors not within his control.

The nature of work that a scientist is required to undertake may be broadly classified into four categories: Basic research, applied research, field work and teaching. The early history of the development of our science reveals that those engaged on basic research work were prompted by an innate desire to probe into the secrets of nature. Workers on applied research were motivated by the desire to mobilise the forces in nature for the betterment of mankind. Thirdly, there were those who were engaged in the actual application of applied scientific knowledge to the various spheres of life. Finally there was the task of imparting knowledge to others who were keen to enter the field of science and this was generally done by those occupied in research work. The passionate desire of a pupil to devote himself to science was a sufficient impetus for his teacher to educate the pupil along proper lines. Teaching and research in science in this country to-day have changed a great deal from what was the case in the past. There is no doubt that both teaching and research are now carried out in a much more organized manner than in the past, but the previous incentive has almost disappeared, while the motivation is poor. It is, for instance, most unusual in India these days to come across a youngster who is obsessed with the desire to devote himself to the study of animal life. It is too well known that in the past the greatest

achievements in any field of science were of those who had, at an early age, felt a very strong urge to work in that particular field of science. To-day, in this country the desire on the part of a young individual to take up Zoology as a career is seldom spontaneous. Study of Zoology is pursued for reasons other than a real and deep interest in the subject. This must be attributed mainly to the fact that we offer very little scope to students to have any opportunities of studying Zoology at an early age. The students are not introduced to the subject of Zoology in the schools, as in the case of sciences such as Physics and Chemistry. Moreover, there are very few well-equipped Zoological Museums in the country to stimulate the interest of the youngsters in the subject. In spite of all this a fair number of students all over the country take up Zoology as a subject during the course of their college studies. The reason for this is obvious. The rules for admission to the Medical Colleges lay down a knowledge of Zoology of at least the Intermediate College Standard as a pre-requisite. Therefore, many students take up the study of Zoology primarily with a view to qualifying themselves for admission into Medical Colleges. Those who fail in this attempt, have no alternative but to continue the study of Zoology as a part of their undergraduate studies. The strong urge for medical profession, however, persists, as is evidenced by repeated attempts by some of the students year after year to seek admission into the Medical Colleges. There are finally a group of frustrated students who join the post-graduate classes in Zoology, not by choice, but by the force of circumstances. The first difficult task of the Zoology teachers, therefore, is to deal with students, majority of whom are poorly motivated.

At the present moment, the selection of a career is based primarily on considerations of earning a decent livelihood. In this respect of all the sciences Zoology has the least to offer and as such it does not attract the attention of those who are likely to be successful in other spheres of life. Those students who are forced to study Zoology under the circumstances mentioned above, can look forward to a career in only a few lines, besides teaching. They join the teaching profession only as a last resort mainly because the low salaries of the teachers are far from attractive. This perhaps does not apply to those who are lucky enough to be appointed directly as readers or professors in the universities, and as such are paid comparatively higher initial salaries. Therefore, one of the evils of the present system of education lies in the fact that a number of discontented teachers in Zoology are entrusted with the training of fairly large number of pupils who do not possess any strong impulse to learn the subject.

Zoology has grown into a vast science and it incorporates such diverse subjects as Morphology, Physiology, Embryology, Ecology, Palaeontology, Cyto-genetics, etc. There are millions of forms in which life exists to-day and there were equally large number of forms which existed in the past. Zoology, in a broad sense, includes detailed morphological, physiological and embryological studies of these forms. A major problem that faces a teacher of Zoology is to select out of this vast ocean of knowledge, a suitable course of studies which could conveniently be undertaken by the pupils during the short period of their under-graduate and post-graduate studies. There is, at present, no universal agreement on what should be included in the syllabus, and on the mode of presentation of the subject. The result is that students who have obtained post-graduate degrees from different colleges develop different concepts of the subject. A particular aspect of Zoology that receives great importance in one University is treated lightly by another. Even the rules for awarding B.Sc. and M.Sc. degrees vary from place to place. The duration of

the course of B.Sc. Hons. is two years at some places and three years at others. In certain places there is only one examination held at the end of a two-years' course for awarding the M.Sc. degree. In others, the aggregate of two examinations, one at the end of first year and the other at the end of second year, is taken into account. In most places examination for M.Sc. degree is by written papers as well as practicals ; some require only a thesis ; while others have thesis in addition to written papers and practicals.

There are some teachers in Zoology who endeavour to introduce specialization in one or more aspects of Zoology fairly early in the career of a college student. They fail to appreciate the fact that the time available to the student is just sufficient to enable him to grasp certain fundamentals and principles of Zoology and to have a general knowledge of the various aspects of the subject. The attempt at an early specialization not only fails to bear fruit, but also leaves very little time for the student to acquire the knowledge of even the fundamentals.

In some colleges the teaching of Zoology is confined mostly to morphology in its pure form and very little attempt is made to emphasize the functional significance of various structures. On the other hand, there are extremists who have recently adopted the view that physiology should form a major part of the syllabus. This view ignores the fact that physiology is in itself a specialized subject the understanding of which requires a fair amount of the knowledge of Biochemistry and Biophysics, and as such a comprehensive treatment of the subject is beyond the scope of Zoology syllabus for college studies.

The presentation of the subject matter often fails to create an interest in the subject. Theoretical aspect of the training is given precedence over the practical aspect. In the very early days of the career of a student, he is presented either with a detailed account of the classification of animal-life or with the names of the numerous parts that constitute the body of one of the animals. To a beginner, then, Zoology means nothing more than the ability to remember and to recognize the various bones and soft parts of the animal. The great importance attached by some teachers to the learning of the names of the various structures creates an atmosphere, not of the learning of a natural science, but that of learning of a language invented by the zoologists. The study of any particular animal form is usually not carried out in the background of the general principles of Zoology, the effect of environment on the origin of the species, the economic importance of animal life etc. The practical classes are utilised for nothing more than giving an opportunity to the students to be able to display, identify, and isolate the various organs from the dead bodies of animals. Very little time is devoted to the study of living animals with regard to their locomotion, feeding, social behaviour, natural habitat, growth, response to various stimuli, etc.

Although many teachers of Zoology do not often appreciate the deficiencies and the drawbacks in the mode of their teaching, their sincerity and eagerness for progress can hardly be doubted. There are others who fully realize that the system of teaching is far from satisfactory, but for lack of proper facilities they are unable to bring about any improvements. In those universities where teaching of Zoology is of long standing there are more or less well equipped laboratories, but in many of the colleges, where the teaching of Zoology has been introduced only in recent years, there is a shortage of both staff and equipment, due to inadequate funds and other causes. In the absence of properly equipped laboratories,

libraries, and museums, knowledge cannot be imparted along proper lines. In the appointment of the staff, due attention is often not paid to the qualifications of the candidate, resulting in the selection of teachers whose basic knowledge is not up to the required standard. Management in most cases is in the hands of those who have no idea of the basic needs of a Zoology Department.

Since organised teaching of Zoology began in this country not more than 50 years ago, and research in Zoology only as late as the first decade of this century, we are naturally much behind the other countries, and even our knowledge of common Indian animal types is far from complete. We are, therefore, dependent for teaching Zoology on foreign text-books which deal mainly with the fauna of their own country. This practice creates a great confusion in the minds of the students. In the teaching of Entomology, which forms a special part of the post-graduate course in a number of universities and is becoming increasingly popular, considerable difficulty is experienced due to the lack of suitable descriptive monographs on Indian Insect types. Even the detailed account of the common cockroach, which forms the subject of study of a beginner in Entomology is either out-of-print or out-of-date.

The difficulties of our teachers in Zoology are many, but they are not, to my mind, insurmountable, and I hope, you will agree with me that a proper appreciation of the problems of our teachers is an essential step for raising the status of Zoology in India.

RESEARCH IN ZOOLOGY

Success in Scientific research calls for several requirements. It is well worth inquiring as to how far these requirements are fulfilled in the case of our zoologists undertaking research work. First of all the research workers must possess certain basic qualities such as a passion for research, clarity of mind, thoroughness, sufficient imagination and intellectual honesty. In the absence of these qualities an individual cannot be expected to achieve much in the field of research. Research workers in the universities and institutes are often required to assess the ability of a trainee for research work, and it is not uncommon to find a junior being reported upon adversely not because of the lack of these basic qualities but due to his inability to produce a research paper in a prescribed period. On the other hand, trainees with very little aptitude for research have often impressed their seniors by producing one or more research papers in a short time, irrespective of the quality of the research work. Similarly in the judgement of the achievements of an individual in the field of research it has become customary to take into account, not so much the quality of research as its quantity.

It is sometimes stated by those engaged on scientific research that since most of the important discoveries have already been made we are not in the same advantageous position as were those in the past when there was still a great deal to be discovered. In my opinion it is more appropriate to say that most of the discoveries that were possible with the use of senses unaided by special instruments, have been made. The precision that we have attained to-day in our instruments used for experimental work offers us greatly increased opportunities to delve into those depths which could not be approached with imperfect equipment available to our predecessors. Therefore, in the present age, availability of the improved equipment is an important requisite for success in scientific research, in

the same manner as success in modern warfare is determined considerably by the type of weapons with which the armed forces of a country are equipped.

In order to enable the scientists, in this country, to further the progress made in some field by the scientists of other countries, it is essential for them to have access to instruments which are at least as precise as those used by the previous workers. There is no doubt that very often equipment required for zoological work is not readily available to our young workers. As is true of all the sciences the equipment required for research in Zoology is of two types—one that is required for work of a routine nature which every laboratory must have, and the other for work of a specialized type. In the past there were laboratories in several universities which were deficient even in the simple equipment required for routine work, but lately this deficiency is being overcome mainly through the financial aid given by the University Grants Commission. The equipment needed for work of a specialized nature is usually expensive and its purchase has to be considered in the light of the financial position of a laboratory. It is the belief of some zoologists that research cannot be pursued on proper lines unless the laboratories are equipped with the latest type of highly specialized instruments. I am not inclined to agree to this view point on the ground that the availability of certain equipment in a laboratory will not necessarily make the workers use it. It is neither advisable nor feasible to allow highly expensive equipment to rot in a corner of a laboratory simply because it is hoped that one day a zoologist would feel the need for its use. An apparatus purchased without any proper plans for its use, has occasionally remained inactive for a long time, and when after the lapse of a few years somebody contemplates to use it, he is perhaps disappointed to learn that it has become obsolete. The purchase of very elaborate and expensive apparatus required for specialized research work is justified only if suggested by one who is convinced that such an apparatus is essential and could be immediately put to use for the completion of a particular project. Once the genuine need for an apparatus has been determined there should be minimum delay in its procurement, as unusual delay in obtaining a much needed equipment has often damped the enthusiasm of a research worker, and retarded the progress of the work.

Since success in zoological, as in other scientific, investigation is determined considerably by the methods employed, the zoologists in foreign countries are always striving to improve upon these and often design new equipment with the help of Biophysicists and Engineers. I was highly impressed by the laboratory of Prof. Gray at Cambridge where he has set up an elaborate equipment designed by him for studying the modes of locomotion of various animals. Unfortunately the zoologists of our country have not yet displayed any enterprise in this direction. We ought to be inspired by the achievements of Late Dr. J. C. Bose in the field of botanical research, who had an extraordinary capacity to design original equipment for the study of various phenomena in plants.

Another important requirement of a research worker is a well equipped library. The inability on the part of a worker to procure complete literature on the subject of his interest is often responsible for a considerable hinderance in his work. Our libraries are far from properly equipped, particularly those in the Universities. It is a happy sign that we are becoming increasingly conscious of this deficiency and are trying to improve the position as fast as possible. The stock of Zoology books in most of the libraries is poor, while the back numbers of even the important journals are usually wanting. As the research students do not have ready

access to many of the original papers, they have to rely upon incomplete information available from other sources. Such practice cannot possibly conduce to a proper grasp of a subject and often leads to misinterpretations of the ideas of the previous workers.

Success of a young scientist in research work depends to a marked degree on the manner in which he has been trained for conducting research work. The research conducted by a student for a post-graduate degree or doctorate often provides only the basic training in the methods of research. But the kind of training that is most likely to lead to the attainment of high distinction in research work is that which a junior scientist receives by virtue of his working as an assistant to a scientist who has distinguished himself in a particular field. Unfortunately such opportunities are hardly available to our young zoologists who are keen on research. Unlike the zoologists in other countries like U.K. and U.S.A. who have established several high class schools of research, the distinguished zoologists in this country do not often train and inspire the pupils who could continue on the work carried out by their teachers during their life time.

Another important feature of research organisation is the maintenance of a healthy relationship between its various members. The senior scientist must be able to guide and inspire the efforts of the junior. He must remember that he has not only to train the junior but also should be prepared to learn from him. The junior scientist must accept the advice of the senior and give him his loyal and devoted support. He has, however, a right to expect that the senior would be kind to him and give due consideration to his ideas and work. How far this relationship exists between the various members of our zoological research establishments, I leave it to your imagination.

During recent years a number of Indian zoologists have had the opportunity to visit zoological laboratories in foreign countries or to work there for variable periods. But it is sad to note that no serious thought, in the past, has been given to the fundamental questions as to what is the specific purpose for which our zoologists need to be sent abroad, the individuals most suited for such work and the minimum duration of their visits. We have not weighed the benefits derived from such visits against the time and money involved. I am personally in agreement with the principle that contact of Indian zoologists with those of other countries not only gives them an opportunity to learn a great deal but also helps to broaden their outlook. But in view of our financial limitations it is imperative to consider whether the expenditure incurred on some of these visits could not have more usefully been utilised for other urgent requirements. As far as the training of our young zoologists abroad is concerned I feel that it should be restricted to cases where it is desired to train a zoologist in those aspects of zoological research which have not been so far developed in this country. The zoologist sent abroad for this purpose should be allowed to stay there for a sufficiently long period to enable him to undertake his work with confidence after his return to this country. Unfortunately in several cases zoologists sent abroad for the purpose find that the periods of their visit are too short for them to gain the requisite amount of experience in the special lines of work. Some zoologists could benefit a great deal from short visits to foreign countries, provided that they are senior zoologists, who have already had sufficient experience in research or teaching, and are thus in a position to discuss their problems with the workers in other countries. This consideration has not invariably been kept in mind in the past with the result that some of the zoologists visiting the foreign

countries have returned with merely visual impressions of the laboratories visited by them, and which does not make it possible for them to offer any suggestions for the improvement of our research or teaching methods.

I may perhaps be excused at this stage for making a brief reference to the output and standard of zoological research in India so far. Progress of zoological research in India up to the year 1938 is admirably reviewed by Dr. H. S. Rao in "The Progress of Science in India during the past 25 years", a Silver Jubilee volume of the Indian Science Congress edited by Dr. B. Prashad. This was reprinted by Dr. B. S. Chauhan for the National Institute of Sciences, India. According to this review the total number of papers published by all workers in Zoology up to the year 1938, is 663, out of which 316 are by foreigners in this country and the remaining 347, by Indian workers. Almost all the papers are of a high standard and are published in standard foreign or Indian journals. A second report published by Dr. Chauhan on research work done in India up to 1950, reveals that extensive work has been carried out by a large number of young and old workers on a variety of subjects. While some of these papers are commendable, others are merely short notes published in *Current Science* or *Science and Progress*, and a very large number comprises of abstracts of papers read in various sessions of the Indian Science Congress. Very frequently stray notes emerging out of some bright ideas are jotted down, and hastily published to retain priority and then forgotten; they are seldom followed by detailed papers. It is evident from this that serious research in zoology has become a thing of the past and very few universities or institutes are engaged on any properly planned programme of sustained research. In universities, which have a record of valuable contributions towards the advancement of zoological research, a large proportion of the present day research programme comprises of work of the students and teachers for incorporation in their theses for the M.Sc. and Ph.D. degrees, but it is curious that a large number of these papers are never published. Besides other factors, insufficient financial aid and the meagre facilities available for research are to a certain extent responsible for the poor standard of research in the Universities. The zoologists in the institutes are much more favourably placed in this respect than those in the universities. Nevertheless, certain slackening in the efforts by the institutes is apparent from the fact that their more outstanding contributions were made in the past rather than in recent years. Since the zoologists in most institutes are not usually burdened with the task of teaching and can therefore devote all their time to research, it is natural for us to expect much better results from them than from those in the universities. The workers in institutes are often conscious of the fact that failure on their part to produce results, particularly of applied value, is apt to lead to the impression that the expenditure incurred on their salaries and research equipment is not sufficiently justified. This constant anxiety in their minds prevents them from making any long-term planning of research, and prompts them to justify their existence by producing hasty results which are not always of a high standard. One of the remedies for this state of affairs lies, to my mind, in the change of attitude of those responsible for granting financial aid. They should allow more freedom to the workers in the choice and methods of research, and should support long term policies which may or may not finally turn out to be profitable. Another alternative is to assign to the research workers some duties of a routine nature, preferably teaching in addition to research duties, so that the workers would not be exposed to the criticism of having wasted their time in case their honest efforts at applied research were not very fruitful.

The research workers employed in the Zoological Survey of India are in a happier position than are those in other institutions not only because they can keep themselves occupied with routine work besides research, but also because the sphere of taxonomic research with which they are chiefly concerned presents a vast and unexplored field for studies. There is no doubt that the Zoological Survey of India has contributed a great deal towards the advancement of zoological research in this country and has added considerably to our knowledge of the Indian Fauna. It continues to be an important research organization, though, for some reason or the other it has failed to maintain the past high standard of research. The Indian zoologists have urgently felt the need of Fauna volume containing the latest information on all groups of Indian Fauna, and for this they have looked forward to the Zoological Survey of India for the past several years. It is hoped that this task would be completed sometime in the future.

There are many Indian research workers who do not seem to attach much importance to the publication of research papers. This is particularly true in case of research conducted in the Universities for the M.Sc. and Ph.D. degrees. The failure to publish the results of such research work, is apt to lead to an unnecessary repetition of work. It is some times urged that many of the research papers remain unpublished due to want of sufficient journals in the country. I do not endorse this view, since, as editor of one of the zoological journals I have often experienced difficulty in securing sufficient material for publication in the journal. Besides there is no dearth of other scientific journals in the country in which the contributions of the zoologists are readily accepted. I also can not agree with those zoologists who are of the opinion that we should not contribute to the zoological journals in foreign countries. On the contrary, I feel that the zoologists, particularly the young workers in this country, should be encouraged to publish their results in standard foreign journals. This would instil confidence in them and make them realize that they are able to produce results of a standard comparable to that attained by foreign zoologists.

Finally, I would like to emphasize the fact that we cannot hope to achieve much success in the field of zoological research unless the administrators incharge of public policy fully appreciate the importance of applied Zoology and are prepared to give adequate support for its development. Unfortunately Zoology in India does not occupy the same high place in the educational and research institutes as do the other Sciences. This is because we have not yet acquainted the public with the immense possibilities of its applications in the various spheres of human life. In spite of his very close association with other living beings it is surprising that the common man in this country should be so ignorant about zoological matters. It is up to the zoologist to diffuse zoological knowledge amongst the public and to remind the common man, that in his every day life animals are his friends as well as his enemies. They form important sources of our food, and they are not only our competitors in regard to our food sources, but also destroy a large quantity of our food resources. They are the means through which we better our health, and they constantly threaten to destroy our health. They form the raw material for many of our amenities, and they destroy our belongings. They live side by side with us as our faithful pets, and they fatally attack us as would our bitterest enemies.

ACHIEVEMENTS IN THE FIELD OF ZOOLOGY

Perhaps the most effective weapon for encouraging our young zoologists is the record we have of the accomplishments that some of our older zoologists have to their credit. These achievements have not only indicated to the budding zoologists the correct path to follow, but have also to some extent helped in convincing the common man of the immense scope for practical applicability of Zoology in various spheres of human life.

Several foreign zoologists rendered valuable services towards the progress of zoology in India and we remember with great reverence the names of Stephenson and Annandale for their fruitful efforts towards the cause of zoological teaching and research in India. Names of Lefroy and Fletcher will ever be remembered for the extremely important work they carried out in India in the field of Entomology. Lefroy's well known book entitled, "Indian Insect Life" will continue to guide the Indian Entomologists for many years to come.

Late Prof. B. L. Bhatia, with very limited resources at his disposal established a school of Protozoology at Lahore. He is the only Indian to have studied and compiled the Indian Fauna on Protozoa. Besides his popular text-book of Zoology which continues to be the standard book for Intermediate Classes, he wrote books in Physiology and Hygiene which serve a useful purpose for studies in Schools.

Late Prof. K. N. Bahl, established a school of morphology at Lucknow. His personal researches in the field of morphology were well recognised all over the world. He was the first teacher to realize that all was not right in the laboratories and the class work, where Indian animals were dissected and studied with the help of foreign text-books. This practice often created confusion in the minds of both teachers and students. In his Presidential address to the Zoology Section of the 1924 Indian Science Congress he stressed the importance of preparing Indian Zoological Memoirs of the L.M.B.C. type, on Indian Animal types. The late Dr. N. Annandale and almost all zoologists greatly appreciated this idea of Prof. Bahl, and he succeeded in preparing eight such memoirs on different Indian animal types. The great good these memoirs have done in the teaching of Zoology in India is well known to every one present here. Each memoir took 3 to 4 years to complete, and having remained in close association with Prof. Bahl, I know too well the labour this work entailed. Prof. Bahl's name will ever be remembered for this great service he rendered in the matter of teaching of Zoology, and every effort should be made to keep the memoir work going.

Dr. Baini Prashad held charge of the Zoological Survey of India for a number of years. He maintained a high standard set by his predecessors Dr. Annandale and others. He was later responsible for a scheme of the development of fish and fisheries in India. It did not take him long to convince the Ministry of Food and Agriculture about the great good he could foresee in such a scheme, which is broadly for the development and utilization of fish and fish resources in India, and he succeeded in establishing a number of Fisheries Stations dealing with freshwater, estuarine and marine fishes. The work and activities of these stations are well known to us all, and we feel happy to watch the high standard of work that is being maintained at Mandapam and Barrackpore. This scheme is highly spoken of by the visitors from foreign countries. After his retirement, he rendered good service in connection with the reorganization of Fisheries Department of the State of West Bengal. The

Ministry of Education has entrusted to Dr. Prashad and his colleagues the task of preparing Hindi Terminologies in Zoology and medical subjects, which in the course of time will be adopted all over India.

Dr. H. S. Pruthi, an entomologist of repute, gained the highest distinction of the University of Cambridge and realized at a very early stage the great damage that was being done throughout the country by insects to crops, stored food and other objects. He succeeded in developing a Plant Protection Scheme, under the Ministry of Food and Agriculture, which has done tremendous good to the country, and created opportunities for a very large number of entomologists and technicians who are busy in control measures against the insect invaders. We know too well the great part this organisation has played in helping to solve the food problem by protecting crops and stored grains from insects. This organisation has also received great appreciation from foreign visitors.

CONCLUSION

I am aware of the fact that in addition to those responsible for outstanding achievements in the field of Zoology, there are others who have made creditable efforts in promoting research or teaching in their respective spheres. To these zoologists, some of the statements made by me with regard to my impressions of zoological research and teaching in India, may appear to be too dogmatic. However, I think that most of you here have little doubt that the system of zoological teaching and research in this country is not as we would like it to be. I have touched upon only some of those obvious drawbacks in the existing system which have attracted my attention. It is likely that you may have much more to add to what I have said. In finding a solution for the specific problems facing the zoologists to-day, the only feasible line of approach is by suggesting suitable measures the implementation of which may be expected to yield the desired results. Without the active help and co-operation of all present here to-day, it is not possible to find solutions for many of the problems briefly referred to above. All that I can do at this stage, is to make a few suggestions on general rather than specific lines.

Our first task is to stimulate the interest of common man in animal life. Some of the methods for achieving this are the introduction of Zoology as a compulsory subject in the schools, establishment of Natural History Museums, Zoological Gardens and Aquaria in various towns, and the organisation of bird watching, natural history and other societies for popularization of Zoology as a hobby. Popular books and cinema films dealing with animal life could be made available for the general public. It should also be possible for the Zoology Departments of colleges and universities occasionally to organise exhibitions for the public.

The present system of teaching and examination needs to be revised. Uniformity in the syllabi for college studies and modes of examination is an urgent pre-requisite. More stress on field studies would considerably enhance the students' interest in the subject. The study of morphology should be much simplified and rendered less monotonous by stressing the relation between structure and function. Teachers for the Intermediate and B.Sc. classes, who often find it difficult to keep abreast with the latest advancements in Experimental Zoology, would be greatly benefitted by refresher courses in the universities, to acquaint them with the latest developments in zoological apparatus and technique.

The part played by the Indian Zoological Memoirs in the teaching of Zoology in India is well known to require justification for continuation of work started by Dr. Bahl. Another requirement in the line of teaching is that of text-books written by Indian authors. Since it is almost impossible for any one zoologist to do full justice to the ever-expanding field of zoology, it is advisable to have a book in which different branches are dealt with by authors who have made special studies of their subjects.

With regard to the manner in which we could raise the standard of zoological research in this country I have very little to say. Opinions differ on the question of how best we can organise research in Zoology. But there is one point on which, I hope, we are all in agreement, and that is the need for the establishment of schools of zoological research where a distinguished worker should have a number of assistants and students working on a particular field of Zoology. No amount of study of literature on any field of Zoology is as helpful to a young worker as his direct association and participation in the work of one experienced in that particular field. And it is the young workers of to-day on whom lie our hopes for the future of Zoology as a science in the country.

To bring about a closer liaison between the various research and teaching institutes, the formation of a central organisation appears desirable. The essential task of the organisation should be to co-ordinate the work of individuals engaged on similar type of research problems and to encourage exchange of ideas, laboratory equipment, library books, and journals etc.

Finally I would like to lay special emphasis on the need for adequately equipped libraries. In demanding financial aid for both teaching and research institutes, the need of the libraries must be given top priority. It is impossible ever to consider the expenditure on books and journals as unnecessary or too much.

I am grateful to you for giving me a patient hearing. I sincerely hope that in addition to all the plans you already have in mind for furthering the growth and development of Zoology in this country, you will also give a thought to what I have presented before you in this connection. I am confident that by sustained and collective efforts of all of us we will ultimately succeed in raising the status of Zoology in India and thereby provide greater opportunities to zoologists to serve our countrymen through a knowledge of the science of animals.

SECTION OF ANTHROPOLOGY AND ARCHAEOLOGY

*President :—*DR. MINENDRA NATH BASU, M.Sc., P.R.S., D.Phil.

PRESIDENTIAL ADDRESS

MUSEOLOGY AND ITS PLACE IN THE STUDY OF ANTHROPOLOGY

LEARNED FRIENDS,

I address you today as your President of the section of Anthropology and Archaeology of the Indian Science Congress Association, and I greatly appreciate the honour you have done me and I hope to discharge my duties in a manner acceptable to you. In accordance with the established practice, I deem it a great privilege to deliver an address on this occasion. I have chosen the subject 'Museology and its place in the study of Anthropology', for this.

The progress of man stands on the spread and acquisition of knowledge, and as such the education of the people is one of the most important functions of the State today. Universities have been set up and schools have been established all over the country for the benefit of the people. But what we learn from books, in the schools, colleges and universities, are nothing but acquisition of knowledge of the records. All the past happenings of the world and the deeds of man are recorded in books and we have thus a theoretical approach to History. In the teaching of scientific subjects laboratories are set up, where the student has the opportunities of visual display and manual technicalities leading to a clearer grasp of the actual happenings. But this is not possible in the case of every branch of study. In the case of geography we may present before the student maps, globes, and other geographical charts, etc. But even this is incomplete for the comprehension of geography. A sphere can in no way be depicted on a plain surface, and maps are only a poor apology for the study of the world's surface. While in studying various other conditions of the earth maps are of little use. So for a better study of geography it is considered necessary to provide every institution with a geographical museum.

Thus we find the necessity of having a museum. Its function and importance are many. Though its actual growth and development is only a recent thing, it may be regarded as old as human civilisation. There are various things which grow spontaneously, but the real importance is realised only when they are sufficiently old. Museum may be regarded as one such thing.

Today the educative value of a museum cannot be exaggerated. To see it with one's own eyes the things as they occur in nature, as they gradually evolved or developed, or as they came into existence with the gradual

development of human activities, or with gradual evolution, is the best method of study and comprehension and this is admitted on all hands. So almost every university in the world today has already started or is at least seriously taking up the task of setting up a museum of its own.

The word Museum* is derived from the Greek word *Mouseion*, which means the seat of the Muses. The name museum indicates a temple of the Muses. Greek mythology tells us that the Muses were the daughters of Zeus, the Greek Jupiter. They were born in Pieria at the foot of Mount Olympus, the mountain of the gods. Nine of them were regarded as divinities who presided over arts and sciences.

We find the word Museum used in its original sense in the Alexandrian Museum,—a temple house dedicated to the Muses, the goddesses of learning. Important collections of manuscripts, products of arts and crafts were placed under the charge of distinguished scholars there. Scholars from different countries used to gather there to learn at the feet of the famous masters whose names have not yet been forgotten,—Ptolemy, Hero, Euclid and others.

The Hindi name for a museum is *Ajab-ghar* (wonder house) or *Jadu-ghar* (magic house). The names clearly indicate that the public have no idea that a museum is not merely an *Ajab-ghar* or a *Jadu-ghar* but a veritable treasure house of knowledge, stimulating the spirit of research and helping education in all its phases.

After the destruction of the Alexandrian Museum nothing was known for long of any attempt at establishing an institution like it anywhere else. The oldest surviving museum established on a sound basis is the Ashmolean Museum at Oxford. Elias Ashmole, an English antiquarian, was born at Lichfield on May 23, 1617. He became a solicitor. As a member of the College of Heraldry he wrote 'The Institutions, lands, and ceremonies of the order of Garter' in 1672. In 1677 he presented to the University of Oxford the first public collection of antiquities in England, now preserved in the Ashmolean Museum. Apart from this, the first great and typical museum was the British Museum, established in the year 1753. The Parliament granted a sum of £20,000 for the purpose. Dr. Boulton has remarked that "among modern museums of national standing the British Museum takes a foremost place". Much later the Fitzwilliam Museum of Art and Archaeology was established at Cambridge and it is now a department of the Cambridge University.

We know that the origin of modern museums is found in the Renaissance of Europe. The revival of interest in the classics led to an interest in the relics of classical antiquity which impelled individuals to collect them. The growth of curiosity arising from the Renaissance led to the collection of materials connected with natural history and science. Towards the latter part of the sixteenth century and the beginning of the seventeenth in the collection made by princes, nobles, or humanists, may be found not merely the prototypes but actual beginnings of some of the great museums of today. Thus the museum of Bologna may be traced back to the collections of naturalist U. Aldrovandi from 1527 to 1605. The armours and coins collected by Ferdinand II at the end of the sixteenth century are also unique for a museum. For the most part great museums of Europe owe their origin to the royal and princely collections which in the course of political changes have become the property of the great kingdoms and republics of today. The museums belonging to municipi-

* French—Musée; German—Museum; Italian—Museo.

palities must be added to these which are, for the most part, the outcome of the nineteenth century.

Outside the British Isles the term *Musée* or Museum is applied to galleries which are devoted to art collections. But in the British Museum the term Museum is almost exclusively confined to collections of natural, scientific, historical or literary curiosities or objects of interest.

Museum, therefore, is not a modern innovation. The first one as already mentioned is said to have been established in Alexandria in 283 B.C. Even evidence of a kind of museum in Babylon, dating considerably earlier, has been gathered from a number of museum exhibits found there. During the Middle Ages museums were in a state of suspended animation. Though there might have been small private collections of curiosities, yet they were viewed only as such and were not treated like the collections in our modern museums.

The functions of a museum are mainly educational and cultural, and not merely housing collections of curious objects, as the Hindi word *Ajab-ghar* or *Jadu-ghar* might suggest. Thus the importance of a museum is twofold :—

It is—1. A place of work for the scholar.

2. A place of instruction for the general public.

Dr. Boulton says, "The Museum is a veritable treasure-house for everybody who thinks beyond the every-day matters of human life. The wisdom and experience of the world are stored up there, and no thoughtful person should leave its door without gaining something from a visit.

"The Museum is a picture book of the history of man, and to study it is to enlarge one's comprehension of what man has done and what man can do. The Universe of man like the Universe of nature, extends its boundaries daily before our eyes ; and it is in our museum that the story is displayed for the visitor to come."

Sir Frederic Kenyon, a former Director of the British Museum, says, "Museums make a man more aware of the world he lives in, of its extension in time and space, of the materials of which it is composed, of the trees and plants with which it is covered, of the animals that have inhabited it from the earliest times, of the activities of man, of his achievements in craftsmanship and art. It illustrates written history and enlarges a man's conception of the possibilities of his race ; so it plays its parts in enlarging his mind, in multiplying his interests and in making him a good citizen." Dr. Goetz of the Baroda Museum has pointed out in his article 'Art display in the Baroda Museum',—"Every museum fulfils a threefold task : The collecting of objects of documentary interest, research based on the latter, and finally visual education by means of identified and classified objects. Only when all these three tasks are fulfilled, a museum can claim to be a valuable public institution". Dr. Douglas Allan has said, "Our task is to collect, to preserve, and to make available for study, not only today but also tomorrow".

During the last century progress has been systematised and museums have acquired a recognised place in the educational life of the civilised people.

The services of the museum to the general public are threefold :—

1. It stimulates curiosity, the gratification of which increases knowledge.

2. In some of its departments it ministers to aesthetic culture. It opens before the visitor the beautiful products of nature and of art. It shows him what man has been able to create, out of clay, stone or metal, or by the use of pigments, and so gives him means of training his taste

and developing a cultivated appreciation of the beautiful ; a service which, in a world where so many live in the midst of crowded ugliness, can on no account be minimised.

3. It provides recreational, intellectual and aesthetic enjoyment.

The educational service of a museum is, or should be, not merely passive but active. It is not enough to build and stock a museum and to leave the lay public to find out its value for themselves. Markham and Hargreaves in their report (*The Museums of India*) say that "Museums provide opportunities for visual instruction which is more direct, impressive and more lasting than oral instruction".

The first museum collection in India began in 1796. The Asiatic Society of Bengal founded in 1784, decided to house suitably in Calcutta the exhibits it had accumulated. In 1814 the society was able to establish proper museum, since known as the Indian Museum, under the care of Dr. Nathaniel Wallich. The museum was divided into two sections :—

1. Archaeology, Ethnology and Technology ;
2. Geology and Zoology

Meanwhile in other parts of India the idea of museums sprang up. In 1819 efforts were made to establish a museum in Madras, but it took a long time to materialise it on a sound basis, i.e. 1851. When the museum was first established it was intended to be a 'central' one with branches and by 1856 six local museums were established at Rajamundry, Ootacamund, Mangalore, Coimbatore, Cuddalore and Bellary, under the care of General Cullen. These branch museum were not much appreciated and in 1861 all were closed down excepting the first one.

In 1851, the Victoria Museum at Karachi was established by Sir Bartle. A few years after (1854) the Pathology Museum, Grant Medical College, Bombay, the first Medical museum in Asia, was opened. In 1857, the Trivandrium (Napier) museum was established and an embryonic general museum (Victoria and Albert Museum) in Bombay first threw open its doors.

It was not until 1863 that museums were established in Lucknow (The United Province now Uttar Pradesh Provincial Museum) and Nagpur (Central Museum) and in 1864 the Provincial Museum (Central Museum) was, in Lahore. After this, other museums were born gradually at Bangalore (Mysore Government Museum), in 1865 ; Fyzabad, in 1867 ; Raipur, in 1875 ; Trichur (State Museum), in 1885 ; Udaipur (Victoria Hall Museum), in 1887 ; Jaipur (Albert Museum), in 1887 ; Rajkot (Watson Museum of Antiquities), in 1888 ; Poona (Lord Reay Industrial Museum) in 1890 ; Baroda (State Museum and Picture Gallery), in 1894 ; Bezwada (Victoria Jubilee Museum), in 1894 ; Bhavnagar (Barton Museum) in 1894 ; and Trichinopoly (Natural History Museum of St. Joseph's College) in 1895.

The twentieth century dawned, Lord Curzon was the Viceroy and there was an outburst of activity for establishing archaeological museums all over the country. The museums were established at Baripada, in 1903, Sarnath, in 1904 ; Agra, in 1906 ; Peshwar, in 1907 ; Chamba, in 1908 ; Jodhpur, in 1909 ; Delhi (fort), in 1909 ; Khajraho and Gwalior, in 1910 ; Bijapur, in 1912 ; Dacca, in 1913 ; Lahore, in 1928 ; New Delhi, in 1929 ; Calcutta (Asutosh Museum of Indian Art, Calcutta University), in 1937.

In India and Pakistan, there are now altogether 120 museums today for a population of 432,000,000. Germany has the maximum number of museums in the whole world—1,700 for 66,000,000 people. Next to Germany, the United States of America has 1,400 for 127,000,000 people. Then comes Great Britain including North Ireland 730 for 46,000,000

people. Turning our glance to the East, we find that Japan possesses 200 museums for 84,000,000 people, while Egypt has 16 museums for 14,000,000 people.

A comparative table consisting of country, population, number of museums and average population per museum, is shown below :—

Country	Population (Approximate)	No. of Museums	Average population per museum
Germany* ...	66,000,000	1,700	39,000
U.S.A. ...	127,000,000	1,400	91,000
Great Britain ...	46,000,000	730	63,000
Russia ...	108,000,000	728	150,000
France ...	41,000,000	650	64,000
Italy ...	43,000,000	420	102,000
Japan ...	84,000,000	200	420,000
Egypt ...	14,000,000	16	875,000
India† ...	432,000,000	120	3,600,000

* Figures mainly from the 'Reports on the Museum of India', 1936, page 3, and from personal information.

† Some other small museums are in existence but they are not fully recognised.

In proportion to its population India lags far behind the advanced countries of the world in having museum institutions. Apart from the archaeological museums at sites, original ones will be fewer still. We are yet to realise the great importance of these institutions. A closer co-operation between a museum and an academic institution is necessary and desirable for the interest of the people of India. In America an academic institution has a museum attached, and where no museum is so attached, the academic institution maintains a regular closer relationship with a museum. In India we are no doubt handicapped in various ways, but smaller beginnings are never unwelcome things.

India possesses mainly three types of museums, they are—

1. Historical,
2. Artistic, and
3. Economic.

Of these three, Historical rather archaeological objects and Artistic museums are widely distributed all over the country. They are mainly of academic value. They do not serve the purpose of any practical utility of the people who daily visit these museums. Historical objects of a museum do not make a permanent impression on the minds of the people in general but awaken only temporary feeling of curiosity. The artistic objects of the museum create some impression at their sight but these do not serve much practical interest of the people either.

The main problem with which the people of India are faced today is their economic problem. That is why in India priority should be given to Economic Museums. Historical and Artistic Museums should be organised at the centre or at the provincial headquarters, but Economic Museums should be scattered throughout the country for the education of our masses, who are mostly illiterate still.

The function of the Economic museum should be to spread knowledge about the modes and methods of living centering round the essential object i.e. food. Human energies are first devoted to securing food, then shelter and lastly protection. This is not only the case in the modern world with

civilised men, but also with the primitive people. In Economic museum the knowledge about the past and existing methods of fishing, agriculture, commerce, industry of different parts of India with reference to the other parts should be exhibited. It is suggested that there should be three types of museums :—

1. **CENTRAL MUSEUMS**—should be organised at the provincial headquarters. Each museum should have a board of research scholars to carry on work in different branches of museum activities.

2. **LOCAL MUSEUMS**—should be organised by the District Boards, Municipalities and if possible by the Union Boards and should be at their headquarters. These museums should work in full co-operation with the central museums particularly on terms of loan and exchange of objects between the two.

3. **MOBILE MUSEUMS**—should be organised by the central museums in close co-operation with the local museums. There should not be permanent stations for these museums. These museums will move from one place to another particularly at the centres of arts and crafts and places of fishing, agriculture and commercial and industrial importance where there is no local museum. The centres of the halting of these museums should be the market places, Dak bungalows or rest houses, police stations and sometimes they may be in tents in the open field of a school compound. In these museums only selected objects for the locality should be exhibited. Further selection of place, and details of objects should be left to the discretion of the board of research scholars of the central museum.

Industrial museums in special localities will be of immense benefit to the people. Very few of us can claim to have seen a piece of the famous ancient Dacca muslin. A museum specially set up at Dacca to exhibit the gradual development of that wonderful texture and a general view of the fabrics produced in other parts of the world, so that visitors might acquire a comparative idea of its excellence, might lead to the revival of the industry. Similarly clay model works of Krishnagar call for a museum there. There are many localities producing excellent articles of brass, bronze or bell metal. These industries can also be stimulated by means of the establishment of local museums. Even museums for agricultural implements and production are not in any way unnecessary in this vast agricultural country. The gradual growth of agriculture from the earliest times to the modern scientific age may be exhibited to the great benefit of the people and it may lead them to further improvements along the line.

During my last tour in Jessore (Now East Pakistan) I particularly noticed the dying condition of the fishing industry. Eastern Jessore, Faridpur, Khulna and the adjoining portions of the country abound in the largest variety of fishes. A properly organised aquarium somewhere in this area, as a department of museum exhibition, will be of immense value to the people in general and fishermen in particular. A systematic study of the growth of the different kinds of fishes, their seasons of breeding and egg laying etc., is essential for fish cultivation and its prosperity. The poor ignorant fishermen of Bengal are being hurled headlong down into the abyss of destruction owing to the want of any proper knowledge of fish cultivation. Thus the zoological side is not overlooked.

Notwithstanding all-round difficulties, it is not too much to expect that our local-self-governing institutions—the District Boards, the Municipalities and the Union Boards will take lead in the matter. They may not organise fully developed museums all at once, but they may prepare the soil and plant the seedlings within their jurisdictions and carefully nurse

them into healthy plants, which in course of time will spread their cooling shade over the people.

Today the lack of technical staff is one of the weakest links in the museum services in India, and this frequently prevents even ordinary maintenance work in museums of India. So museums all over India should have trained personnel for carrying out museum work properly. Training for collection of specimens, packing, labelling, cataloguing, cleaning, preservation, reconstruction, and exhibition should be given to these personnel. The central museum as suggested above, should organise both theoretical and practical classes for training candidates for museum work. Besides these, stress should be laid more on the applied aspect than on the academic. Under the guidance of the board of research, cinematographic shows can be arranged and propaganda booklets published to teach the people how to adopt new methods for the improvement of agriculture and of local industries.

For the existing museums in India the following may be suggested :—

1. Central museum with co-ordinated smaller units.
2. Technical departments to be adequately represented.
3. Efforts to increase the cultural and educative value of museums.

The fourth report to the Lord Commissioners of the Treasury of the Standing Commission on Museums and Galleries was published on 1st April 1954, London.

The suggestions are :—

1. "The first of these is the need for museums to progress and not remain static, and for this more space, more money, more staff are continually required.
2. "The second issue is the need to gain full acceptance for museums as 'part and parcel' of education and not merely a 'tepid general recognition of the fact that they contribute something towards' it.
3. "The third issue is the possibility of setting up a body on the lines of a University Grant's Committee."

These suggestions should also be implemented in India for the museum institutions.

In India the maintenance of museums is limited to three types only. In these days of science, Science Museums should also occupy a special place. We are popularising science among our masses, but why should we not have Science Museums for our people? A science museum should represent all the branches of science.

Museums are one of the major limbs of our education. It can be said that education is the responsibility of the school, college or university and that training is upto the museum. Mr. V. L. Devkar has justly remarked "This is true as far as it goes but does not bring out the fact that there should be education at the college or university in what lies behind museum methods, as well as in the subject matter of Art, Science or History and that there should be training at the museum in the curatorial use of scholarship as well as in the methods of administrative, educational and technical work pertaining to the museum." Academic institutions do not give practical facility to the material world. The teaching of Anthropology in the university gives a broad based knowledge of the physical and cultural aspects of Man pertaining to research activity of different aspects of mankind but that teaching is not properly calculated to make a thorough acquaintance with different groups of men and their practical and applied

aspects by collection and preservation. This is one of the important functions of a museum. So the educational facilities offered by a museum should result in a successful teaching of the various subjects by the collection in a museum. This can be done systematically by the department of Museology.

Museology is a coined word which finds frequent use in English language. It means the science of museum i.e. the methods of cleaning, preserving and arranging museum specimens.

The subject museology is of recent origin. Some of the American Universities have already started the course of study. The University of Iowa was the first to lead this course in 1908. Since 1920, the number of places where this course has found place, has grown to 17. In America there are at present nine such training centres. The New York museum and the University of Wisconsin are now running this course of training. In Harvard University museum training is imparted to students with the help of Fogg Art Museum. The Museum Association of London has opened a diploma course in Museology.

Museology is a subject of comparatively recent growth in India. It is practically in the embryonic stage. Its pressing demand has attracted the scientists in recent times. The object and scope of the subject are of utmost importance in order to study human civilisation. The different phases of human civilisation have been recorded by their arts and crafts that can stand the inroads of nature for all times to come.

Museology under the name of Museum Method was introduced in the curriculum of the Post-Graduate classes in Anthropology of the University of Calcutta, as a special paper in 1936. Mr. T. C. Das drew up the syllabus and commenced work with me. Later on Prof. K. P. Chattopadhyay joined the University of Calcutta as the Head of the Department of Anthropology, and began teaching the subject jointly with me. It was under the auspices of late Dr. Syamprasad Mookerjee that a laboratory attached to the Asutosh Museum of Indian Art, Calcutta University, was opened in 1941 by Mr. D. P. Ghosh, the curator of the museum for the spread of the knowledge of the much needed science of Museology. Later on a proposal was made to open museum training classes but unfortunately due to the international situation the proposal could not be given effect to. In December 1954 the Department of Anthropology, Calcutta University started a certificate course on Museology for a period of three months. Besides these, the Maharaja Sayajirao University of Baroda also started a department for imparting post-graduate training in Museology in 1952.

Museology is principally divided into two broad sections: (1) arrangement and (2) preservation of museum specimens. Besides these two, collection of specimens from the field and storing them in the museum house before arrangement for display are also taken into full consideration.

For the collection of specimens one has to go to the field and to contact the people concerned. For the collection of natural specimens (like the objects of Geology, Zoology, Botany) one shall have to take the help of the people of the locality. But for the anthropological specimens he will have to make a closer relationship with the people. Pitching the tent or settling down in a village an anthropologist has to face the initial problem of contacting the people. The sorting out process is crucial to success in field-work. First of all an anthropologist should begin to make friends with the people. Field experience will soon teach him that no matter how different in somatic characters or cultural habits a people may be, there will always be some among them with whom the

relationship will be close. Exclusive use of observation or entire reliance on one informant is not desirable. To take a walk through the village is helpful for the first day's impression of the people. Curiosity will bring the people to one's dwelling, contact will be established. Where such contact is not established, observation and casual conversation may, for some days, be the only source of information. Informants are essential particularly for an anthropologist to collect specimens from the field. In anthropological field-work the conception and the approach derive from the fact that the problem is essentially human in nature. An anthropologist should talk with full affection to his friends among the people from whom he wants to collect his required specimens.

The numbering of museum specimens is very essential. The numbering is to be done immediately after the collection and that should be done with enamel sapolin in the case of wooden or bamboo specimens and Reeve's waterproof ink for metallic and fabric specimens. After numbering with sapolin complete 48 hours, and with waterproof ink full 72 hours should elapse before any treatment should begin.

Storing of museum specimens also forms an essential part. The store room should be a dry one and should have free circulation of air. If the specimens be not taken proper care of they will not endure long.

Record-keeping of the museum specimens is also an essential thing in operating a museum. There should be an Acquisition or Accession Book of the museum. Particulars should be entered in this book properly mentioning how a specimen has been received in the museum either by purchase, gift or exchange. Acquisition number should always be entered. These numbers should be consecutive and must not be confused with the classification numbers.

Arrangement of the specimens for exhibition in the museum should be done properly. Exhibition is perhaps the most difficult aspect of the subject. Things may be arranged either in order of their distribution or evolution. A particular thing should be so placed that its actual importance might not be minimised by other things of the same nature. Arrangement of the specimens should be done in a way that would be interesting as well as educative to the lay people alive.

It has been experimentally seen that casual visits to the museum are of little value and that circulation of odd specimens has many drawbacks particularly among the school students. In order to ensure permanent effect, a course of nature study should be established at the museum. School students should better proceed to the gallery where the following subjects should be illustrated :—

1. How animals move about ;
2. How animals feed ;
3. How animals protect themselves ;
4. How animals care for their young ;
5. Beaks and gills, wings and feet of the birds ;
6. The vertebrate skeletons ;
7. Life in the sea—Reptiles, snakes ;
8. Friends of the farmer.

The explanatory labels should be brief and in simple language. The animals of different types of the locality should be exhibited and the labelling should be confirmed to the popular names of the species.

As there are different branches of study, different sections or departments should be set apart for the different set of collections. Chronological aspect of arrangements may be regarded as one of the important things to be borne in mind, specially in Historical and Archaeological

sections. The arrangement should be such that even a general survey may be sufficient to give an idea of the gradual development of human activities and of the evolution in nature.

Besides, it is simply impossible for a particular individual to collect or study the whole material culture of a given race or country. Museums enable such independent investigators to make a comparative study of such specimens and cultures. By means of a museum the whole culture of a country can be represented vertically or horizontally which serves a ready explanation of the whole thing even to a layman casting a simple glance over it. Lastly, in a museum the records of a dying out culture can be preserved which are very useful for later studies.

The specimens in a museum for Physical Anthropology should deal with (1) Ontology—from conception and embryonic evolution to maturity, decay and death; (2) secondly, it should deal with Phylogeny—the development of species from lower form of life and the evolution of every part of its frame.

In an Ethnographical museum the specimens may be arranged (1) to illustrate the culture history of mankind; i.e. it should exhibit the evolution of the different types and stages of material culture; (2) secondly, in such a museum the distinctive characteristics of various races and peoples with whom the culture is associated should be demonstrated. Mural in the ethnographical gallery devoted to the aboriginals should be situated at eye-level and not immediately under the ceiling.

When the material culture of a particular people is to be shown, the specimens should be classified on the basis of geo-ethnic groupings, i.e. systematic arrangement of the traits and specimens relating to a particular culture should be made. They are as follows:—

I. PRIME NECESSITIES.

1. Collecting and digging out of food materials—Implements used and samples of food materials.
2. Hunting—Implements used and the relics of hunting or games.
3. Fishing—Implements used and the specimens.
4. Cattle and poultry—Implements used and samples of products.
5. Agriculture—Implements and samples of products.
6. Habitation—Materials used, models and parts of shelter.
7. Fire-making and cooking—Appliances, utensils and other household objects.
8. Dress and ornaments—Nature and types.

There are other objects which are also the parts and parcels in the life of a people. They are:—

II. ARTICLES FOR COMFORT—without the articles of comfort, the primary necessities of life can not be fully realised. Such articles can be arranged in the following ways:—

1. Preparation of raw materials for food.
2. Devices for preservation of fish.
3. Oil press.
4. Clothing, spinning, showing the materials, implements and products.

III. ARTICLES OF LUXURY—These articles may or may not be needed in the daily life of a people. They are the signs of the cultural development of a people and can be arranged thus:—

1. Ornaments.
2. Objects used in games, music, dances etc.
3. Works of Art.

Besides all these, there are articles of religion which show the peculiarities of a people.

In addition, there are articles which show the march of modern civilisation. They are:—

IV. **TRANSPORT**—Methods and conveyances on air, land and water.

V. **ARTS OF COMMERCE**—Materials prepared for commercial purposes, systems of exchange i.e. barter and gradual development of currency.

VI. **MEDICAL AIDS**—Indigenous products for medical purposes, gradual adoption of modern system of medical services by showing models of hospitals, dispensaries and clinics.

VIII. **EDUCATION**—Traditional system of education by showing relics of books, manuscripts, etc. ; Models representing gradual adoption of modern system of education and also exhibits in the form of books, note books, black boards, globes, lantern slides and other aids of modern education which have been taken up by the people concerned.

If the procedure of arrangement of the complete materials of the people is followed, a complete dynamic picture of the people concerned would unfold itself to any one. By this one will be able to learn the stages of cultural development and the trend of development of the people concerned.

In the case of geo-ethnic grouping for arrangement the following should also be necessary:—

1. A map of the area (concerned).
2. Models and photographs illustrating the important aspects of life.
3. Models for actual specimens of house types and household objects.
4. A systematic placement of other objects and their photographs.

But in both cases (culture history and geo-ethnic classification of arrangement) a small hard paper or wooden pyramidal board for each specimen with the following notes will give an idea at a glance.

1. Serial Number.
2. Name of the specimen with English Equivalent.
3. Locality.
4. Tribe.
5. A brief description of its use.
6. Museum Number.

Today I would like to speak a few words on the display of folk-life material. We have long been accustomed to museum collections of old and present and these collections are systematically classified and attractively displayed but they do not, in isolation adequately portray a living culture. To exhibit the materials of a living culture adequately in the show cases is impossible. Such exhibits give us part only of the picture. The exhibits in the show cases give the impression not only that they represent merely the dead past, divorced from the present, but the natural tendency is to select and to acquire only pieces for such exhibits. A museum which represents the natural setting and environment of the life portrayed through the exhibits is called a Folk-museum and the method is known as the Folk-museum method.

There can be no doubt that the public museums are the best media for the display of objects related to man and his environment since the

factual, sincere and disinterested atmosphere of a good museum is preferable to and is probably a more acceptable vehicle than special exhibitions arranged by interested organisations which may be at times accused of partisanship. In recent years the greatly improved museum displays show that there is in the museum the knowledge of display technique. We should be sure of these things before we start on planning a museum:—

1. What is its purpose,
2. For whom it is intended,
3. With what it should deal.

“A thing of beauty is a joy for ever: Its loveliness increases; it will never pass into nothingness.”—The poet has said this truthfully in the sense he has intended but he is neither the Director nor the Curator of a museum. Interpreted with prosaic literalness, the assertion is diametrically opposite to the truth. Directors or Curators know full well that tapestries fade and even are devoured by insects; that paintings grow illegible; and that other objects become brittle and fragile. Such decays are inevitable at all times but in old days there was no way of preventing them. Today the task of giving life to these decays has become possible and hopeful. We feel that, when a collection of valuable material is housed in a museum, we have more considerations than those of historical research, documentation, etc. There are also basic problems of scientific and technical nature, which we realise through the success of science in solving similar problems in other fields. They concern the rational care of these valuable exhibits, anticipating wherever possible the causes of decay, finding out methods for preservation and restoring to a permanent condition where decay has already set in.

Within the last decade, the chemical control of bacterial pests have been astonishingly strengthened, first by the discovery of sulphonamide drugs, more recently by penicillin. Another outstanding product of an insecticide is D.D.T.

Museum specimens should be arranged and kept as far as possible in the original condition in which they have been found or collected. Unfortunately we are surrounded by natural enemies on all sides. Our enemies are not only trying to destroy our life, but also our past records that may help us in our march onward. It is an onerous task to preserve museum specimens. But at the same time all-engrossing human activities i.e. scientific researches are finding out means of saving their records from the invasion of hostile forces. The destructive agencies of museum specimens are mainly of two kinds:

1. Climate—i.e. variation in temperature and moisture, affects most articles and gradually causes deterioration in them. It is necessary to adopt means to keep the specimens in equable temperature in dry places. Scientific preservatives should also be used to secure them against variations of temperature and moisture.
2. Insects—of various kinds also eat into the articles of wood, bamboo, leather, fabrics, etc. Careful treatment by chemicals is sometimes essential in preserving the life of specimens. But though now-a-days the great majority of insect pests are being controlled in all countries by this direct method, yet there are a number of such pests which stands such control by this method. In such a case a detailed study of the environment of an insect is of primary importance in evolving practicable measures for control. All forms of animal

life are so intimately adjusted to their respective environment that any change in the condition exerts a significant influence in favour of or against the organism. If an animal is not fitted to its environment, ultimately it will cease to exist. Therefore we can control and change the whole habitat of the injurious insect if and when we know accurately its conditions of environment. The environment of an insect primarily depends on three types of elements :—

- (a) Media—These are air, soil and water.
- (b) Factors—
 - (i) Physical—heat, light, atmospheric humidity and pressure, moisture, wind, rainfall etc.
 - (ii) Organic—parasites, nutrition, food-supply etc.
- (c) Controls—
 - (i) Topographic—latitude, longitude, altitude, slope, high-lands etc.
 - (ii) Climatic—time of the day and seasons of the year.

Various factors of environments are light, temperature, humidity and rainfall, air currents and climate.

Considering the importance of museology the preservatives for different kinds of specimens are discussed here. The methods described are used by me and on actual experiment I have found them very effective though some of them are in use in different museums of the world with slight modifications, and some are my own original works.

Records of 26,452 specimens have been made on the basis of the study described in the discussion and all the cases are included in this study. Records are kept in the following way for each and every specimen :—

Name of the specimen—
 Museum number—
 Condition of the specimen—
 Date of treatment—
 Reagent used—
 Date of inspection—
 Humidity—
 Remarks—

Since 1936 I have been using them in the laboratory in the routine way as well as in the field, with a view to preventing the specimens from the attacks of the destructive agencies.

Preservatives may sometimes prove very costly. But the question of the importance of the specimens should be the criterion to decide whether such costly things should be used. Apart from the question of a museum, the preservatives discussed here will be of great help in the preservation of our household articles of every day life. Here no doubt the economic question is vital. But some of the preservatives mentioned here, which are giving good results, will be found to cost very little and are not very difficult to handle.

Preservation of museum specimens falls under two sections :—

- (1) Method—The composition of the material of the specimen is to be ascertained.
- (2) Application—Any change or deterioration of the specimen is to be determined, and suitable means should be adopted to remove the cause or to counteract the destructive elements.

But the injurious conditions for preservation are many. The conditions, their actions and methods of control are shown in a tabular form :—

<i>Condition</i>	<i>Action</i>	<i>Method of Control</i>
1. Sun light ...	1. Fading of colour 2. Softening 3. Brittle and fragile	Administering yellow tint in the background
2. Moisture ...	1. Fading of colour 2. Formation of bacteria 3. Action of salt	1. Proper ventilation 2. Use of calcium chloride
3. Atmospheric condition.	1. Deformation of specimen 2. Other changes and damages	Temperature control room
4. Dust and Dirt ...	1. Accelerate the growth of bacteria and fungi	1. Occasional cleaning 2. Use of dust and dirt proof show-case
5. Bacteria and Fungi	1. Damage the specimen (damage specially the cellulose material)	Keep specimen in dry condition
6. Insects ...	Damage specimen—specially of organic materials	Two ways— 1. Preventive—by frequent inspection and cleaning and keeping naphthaline balls, camphor cakes, raw lime or a powder of orris root, clove, black pepper and cinnamon 2. Curative—by fumigation with carbon-di-sulphide or formaldehyde or thymol.

The most dangerous enemies of museum specimens are white ants or termites, cockroaches, and various types of wood-boring and book worms, silver fish, mildew, rats and mice. A table is given below to show about the injurious enemies, their habitat and remedial measures :—

<i>Name</i>	<i>Habitat</i>	<i>Remedial Measures</i>
White ants or Termites.	Damp places	1. Crude creosote solution diluted with Kerosene oil 2. Sometimes only Kerosene oil 3. 5% D.D.T. Solution Sprinkling of Borax
Cockroaches ...	Fond of colouring matters, of cloth bindings etc.	1. A cotton swab soaked in spirit turpentine 2. Benzene Application of copal varnish
Wood-boring insects	Damp wood, old wood and sometimes in books of antique papers	Application of cedar wood oil or birch oil
Silver fish ...	Dusty places and dark corners	1. Eucalyptus oil 2. Carbon-di-sulphide 3. Turpentine Caustic Soda.
Mildew ...	Formed specially on leather and sometimes on damp wood in damp climates	
Rats ...	Dark corners of the room	
Mice ...	Dark corners of the room	

An arrangement of the methods of preservation of museum specimens needs thorough step-by-step treatment.

They are :—

I. Cleaning—It is the first step in restoration. This may be done in the following way—

(a) Dusting—By means of a small soft camel hair brush or a small pair of bellows.

(b) Washing—This is done normally by ordinary tap water, distilled water for clay materials, acetone and rectified spirit or absolute alcohol for ivory specimens, potato or onion juice for oil painting, warm water or sometimes very dilute acid and then changes of tap water for metals like copper or bronze.

But two very important things should be taken into full considerations.

(1) Patience, and (2) necessary time to be observed.

II. Repairing—The next step is repairing, which means mending. Mending does not mean the addition of new materials but refixing of broken or loose parts. This involves training and care, patience, experience and manipulative skill.

Adhesives recommended for use in repairing, are :—

(1) Glue for wood.

(2) Celluloid cement for glass, porcelain, quartz, and flint.

(3) Plaster of Paris for stone and pottery.

(4) Paste made of white portion of egg and flour for porcelain.

(5) A solution of sodium silicate and fine stone dusts for stone.

(6) A mixture of country made cement and sand for fire-baked clay i.e. terracotta.

(7) Wax for ivory.

III. Strengthening—A very fragile and delicate specimen to be secured for its safe existence, should be impregnated with any of the following reagents in the liquid form :—

(1) Celluloid solution.

(2) Plaster of Paris.

(3) Linseed oil.

(4) Melted Paraffin.

(5) Melted bees-wax.

(6) Green mangosten extract (*Diospyros Embryopteris*).

IV. Renewing—The process of addition made to complete a broken specimen is known as renewing. Care should be taken so that the addition of new material may be as much as possible like the original.

Cleaning and preservation of museum specimens can be conveniently grouped into three main categories :—

I. Organic specimens

(a) Wood and bamboo.

(b) Fabrics.

(c) Paper goods.

(d) Leather.

(e) Ivory and bone.

(f) Pictures and Paintings.

(g) Leaves.

II. Siliceous specimens

(a) Clay.

(b) Glass.

(c) Stone.

(d) Fossil.

III. Metallic specimens

- (a) Copper and bronze.
- (b) Silver.
- (c) Gold.
- (d) Iron.

Here I shall relate before you the brief sketch of the methods of cleaning and preservation of some of the museum specimens.

For the preservation of wooden and bamboo specimens in museum against insects carbon-di-sulphide vapour and crude creosote diluted with kerosene oil are quite effective. Fresh excavated wooden specimen is generally damp. It is to be dried otherwise shrinkage and warping may be so great as to cause irreparable loss. It is to be dried in a cool place for a few days. After drying, the specimen is to be immersed in celluloid, vinyl-acetate or paraffin otherwise the natural food-stuffs (starch etc.) in the wood will attract insects.

The wooden or bamboo specimen is washed first with 5% carbolic soap and washing soda. Fuller's earth (*Sājimatī*) also gives satisfactory results. After drying the specimen in the room carbon-di-sulphide vapour is applied by placing the specimen in the carbon-di-sulphide chamber. If the problem of having moth etc., in the specimen be still apprehended it should be subjected to creosote treatment. After that the specimen is to be exposed to an open place to dry up. Full 72 hours are required for complete drying. Next step is to paint 10% shellac solution. A solution of green mangosteen (*Diospyros embryopteris*) and neem (*Melia azadirachta*) preparation may safely be used as a substitute of shellac solution. Any coloured or pigmented specimen should be treated with thymol vapour, when attacked with insects. Thymol is a powerful fungicide and in museum and library it is used quite safely.

Formaldehyde fume is very effective for the preservation of fabrics and paper goods. The specimen should be brushed or dusted carefully. It is then subjected to formaldehyde chamber for fumigation. The specimen is to be taken out after 24 hours. To dry up the the little water it absorbs from fumes in the chamber the specimen is to be kept in open air for about half an hour. After this the specimen can be safely placed in its original position and a country made preservative powder--orrisroot (*bach*), cloves (*labanga*), black pepper (*golmorich*) and cinamon (*daruchini*) in equal proportions should be kept in small cloth bags and placed on the shelves or racks alongside the specimen.

To study the effect of actinic rays on paper and ink, a universal ultra-violet lamp is necessary. For old papers and faded writings physical method of examination under ultra-violet rays is effective, though the method involves certain technical difficulties. In the absence of this, Japanese tissue paper or chiffon may be used. Ordinary tissue paper may also serve the purpose, but it should be gummed by a gloy made insecticide. Mercuric chloride or copper sulphate is used for this. For repairing work the use of an adhesive is essential. An adhesive substance is generally made of starch material which is a good food to almost all the book insects. So to make the adhesive insecticide and fungicide a preservative is to be used. Dextrine of B.C.P.W. may be used safely. But the juice extracted from green 'Bael', wood apple (*Aeglemarmelos*) is recommended for this.

Old and brittle papers can be reinforced with Japanese tissue paper or chiffon. This also increases the resistance to handle but does not protect them from time span deterioration. The Japanese tissue paper quickly turns brown and becomes opaque and brittle in course of 5 years. It is also less transparent than chiffon and is not much suitable to moist

climate. It is not an easy task in the application of Japanese tissue paper and is also very difficult at the time of removal when required. Chiffon is more transparent, durable and easier in both application and removal. It becomes opaque and brittle in course of about 25 years. So chiffon is superior to Japanese tissue paper. The only disadvantage is its high price. Latest researches show that the reinforcing of old and brittle papers and of increasing their resistance in handling give satisfactory results with cellulose acetate foil used for lamination of old and brittle papers by the application of heat and pressure in a hydraulic press. The method claims its superior and advantageous position to all.

Sometimes it is seen that old documents which are badly damaged by oil and are almost illegible may be washed with a solvent viz. benzene and repaired. The removal of oil by this treatment will not weaken the fibres of the documents.

Prints suffer very much due to discolourisation. This may be removed by the following treatment. First of all over-hanging dusts on the prints should be removed by means of a soft brush. After this the print should be placed in a shallow steel dish containing ordinary water and subjected to sun light exposure for 2 or 3 hours. After this the prints will be free from discolourisation and then cleaned and dried up by white blotting paper and they should be placed in between two fresh blotting papers with a uniform pressure. If the discolourisation caused by mildew is considerable, a bleaching agent should be used.

Cleaning of oil-paintings is not only a fine manual work but also requires a clear knowledge about the constituents of the pigments, mediums, varnishes and chemicals used in them.

One per cent Saponin solution is a good reagent for cleaning dirt and smoke deposited on an oil-painting. A cotton swab damped in methylated spirit can be applied on an oil-painting for cleaning, immediately followed by another cotton swab damped in spirit turpentine. Care should be taken so that the time between these two applications does not go beyond one second. The application of one-day old bread crumb on an oil-painting in the way of an India rubber fashion is another method for cleaning. The use of potato or onion (juice by a cut) is the simplest and cheapest method for cleaning oil painting.

The leaves in the museum to be preserved are to be dipped in a solution of 4 gms. of mercuric chloride and 200 c.c. of 75% rectified spirit and dried on a blotting paper. Finally they are to be fixed on a cartridge paper by means of a silk thread. Before thus stitching the leaves the thread is also to be dipped in the above solution. For cleaning of dried painted leaves, specially palm, juice of country beans is recommended. Palm-leaf manuscripts with incised drawings can be safely cleaned by the application of the juice of green 'pui' (*Basella rubra* b).

Leather is not a permanent material. In course of time its property changes—much change is noticed when it is not dressed. This change may be prevented by regular application of suitable dressing to lubricate the tissues and to get it free from air and sulphur acids. Castor oil, lanoline or vaseline are agents for such dressing. The leather preservative mixture known as 'British Museum Leather Dressing Solution'* is used for this. But oil extracted by dry distillation from seeds of 'Seal Kanta' (*Argemon Mexicana*) gives satisfactory result.

* Ingredients—Beeswax—7 gms.; Lanoline anhydrous—100 gms.; Cedar wood oil—14 c.c. and Hexane—170 c.c.

Clay specimens should be divided into three groups:—

1. Fire-baked—This should be washed in distilled water and after drying a coat of celluloid solution or 5% shellac solution should be applied.
2. Sun-baked—This should be cleaned by blotting paper soaked in distilled water and the same preservative mentioned above should be applied.
3. Unbaked—This should be cleaned with paper pulp soaked in distilled water and wrapped over the specimen for a second only. The preservative as mentioned above should be applied.

Ordinary glass can be cleaned by chalk dust and methylated spirit solution. Scratches and other defects on the glass can be removed by xylol and metnylated spirit and finally cleaned by emamois leather. The fungus of the glass lens can be cleaned by dilute hydrochloric acid and xylol as suggested by Mr. T. C. Bagchi.

Iron corrodes very rapidly in a damp atmosphere. It is also noticed that iron corrodes more quickly on the sea coast due to the presence of salt in the atmosphere. The corrosion may be checked by the application of a few chemical reagents. Pyruma putty is used on heavily rusted iron specimens. The use of kaolin or china clay made into a paste with sodium silicate solution gives similar result. The use of three-in-one oil gives satisfactory result. Durophene diluted with benzol or vinyl-acetate dissolved in toluene forms a suitable reagent. Exclusion of moisture and air is successfully employed by the Department of Geology, Field Museum of Natural History, U.S.A., on iron specimen. The chemical used is stanolax oil. Linseed oil is also a good preservative.

When a copper or bronze specimen is corroded beyond recognition, washing under hot running water is necessary. The last bath should be given in distilled water. When it is dried a coat of 2% celluloid solution is to be applied. But when the specimen is heavily incrustated but retains the metallic core, treatment can be satisfactorily carried out by the application of 2% citric acid. For cleaning copper or bronze and removing the incrustations deposited on the metal, a solution* of ammonium chloride, stannous chloride and dilute hydrochloric acid, has been used with much success. After washing the specimen should be painted with stanolax oil to get it free from moisture and air. For cleaning of copper specimen rubbing with the leaves of *Oxalis corniculata* has proved very successful. Mr. T. C. Bagchi has cleaned a number of copper and bronze and iron specimens with ammonium sulphate and ammonium persulphate in the Museum Method Laboratory of the Department of Anthropology, Calcutta University with much success. The recent experiments with D.D.T. against insect pests like wood-boring insects, silver fish, white ants, etc. give satisfactory results. Besides, various other insecticides viz.—

- (1) D.F.D.T., apple scented German cousin of D.D.T.
- (2) Methoxychlore—Man's chemical warfare against the insects has been reinforced by a cousin of D.D.T.
- (3) Ryanodine.
- (4) Killoptera, etc.,

are in use in many museums.

* * * * *

* Ammonium chloride—10 gms.; Stannous chloride—10 gms.; Dilute Hydrochloric acid—30 c.c.

Since mankind is considered as a part of nature it is no phenomenon to find the presentation of mankind within the framework of a museum of Natural History. Many museums of Natural History however, only display the models and photographs of the different peoples, and not their way of life. One part of mankind is put in the museum of Natural History and the other part is given a separate place as other thing whose way of life receives the specific term culture. Physical and cultural anthropologists are thinking the whole position of the human being as a part of nature and as an exponent of culture.

Ethnographic museums have a specific function in modern human society and they are of fundamental importance for international comprehension. The way in which they fulfil their function depends whether influence must be regarded as beneficial or harmful. Their beneficial influence does not mean that it is their duty to propagate lofty human ideals as scientific truth. Their harmful influence is not confined to a deliberate propaganda of racial discrimination. Museums give information on the present state of anthropological science to the public. They also tend to confirm the preconceived notions of many visitors on the different peoples, which are influenced by traditional ideas and sentiments and concepts of previous stages of anthropological science. Ethnographical museums have to recognise that there exists at the moment a great discrepancy between preconceived ideas and vague notions of most of the visitors and the present state of anthropological science.

Agriculture, commerce and industry form the most important institutions in modern human life. These are the sources of livelihood of millions of people. Let us examine what part anthropology and museum play in these institutions of modern human culture. In Chotanagpur area in the interior the tribal people purchase glass beads and bangles of the local markets. These come usually from Japan. The secret of Japan's success lay in her microscopic observation of local taste. Before the last war I know personally that Japan had one commercial museum in Calcutta. People were sent to distant villages to study the villagers and their fancy, and special likings were collected, two in number for each and every article—one being kept in the museum and the other sent to Japan. In this way it was possible for Japan to capture the Indian markets. Recently Prof. N. K. Bose has studied the Cambay microlithic industry of Western India. He has shown that the stone beads from Guzerat are usually sent to the Africa markets for sale. The Guzeratis have studied those people particularly of their hobbies. The Guzeratis are now earning thousand of rupees by this. Another feature in the life of a people is dress and ornament. The tastes for these are also changing with the time. Social, political and economic factors contribute much towards the formation of the styles and fashions of the people. I may mention here the use of the Hawaian coat today by the Indians. Numerous examples are before us and they show that an intimate knowledge of social, and economic life of a people is necessary for a successful supplier to the market. This requires a co-ordinated knowledge of anthropology and museum. Now-a-days shops have taken up the caption 'museum' like 'Shawl museum', 'Shoe museum', etc. So also in agriculture it is possible for an anthropologist to study the condition, nature of the soil, climate and the products and for further improvement as well as for good markets a trained anthropologist will always insist on instituting a good museum. Hence, supplying information to agriculturists and industrialists regarding the demands of articles for a particular market, the anthropologist with the help of a well-arranged museum can be of much help to them. Then what is the

relation between a museum and an anthropologist i.e. the relationship between the Science of Museology and Anthropology? In one word it can be said that museology is an experiment in applied anthropology.

It has been a common belief in the academic sphere that men have passed their earlier days through four major stages of livelihood—food gathering, hunting, pastoral and agricultural. In each of such stages we see among them a particular way of their effort—the foodquest which is again accompanied with a distinct group of implements or technological and archaeological equipments. Whatever we could see beyond the historical reach into the early human life, purely depend on the prehistoric and archaeological finds which are in the main based upon the material culture of the remote folk, which we could study from the well-arranged museum by the branch of study known as museology. Whatever we could trace in the trend of evolution of man and his culture, is therefore, mainly dependent on the study of museology which thus forms an essential part of both physical and cultural anthropology.

The inter-relation between museology like material culture and other branches of anthropology, however, has been a matter of much controversy. Here I should mention specially the observations made by Dr. Hutton in his presidential address of the Royal Anthropological Institute, London in 1944. He points out that the prevalent view among the British anthropologists of the last generation regards anthropology divisible into three sections—physical anthropology, social anthropology and material culture. To this Hutton remarks—"The old three fold division of anthropology into physical anthropology, social anthropology and material culture appears to me obsolete. I should prefer a two fold division into physical, which would include both anatomical and physiological aspects of the science, and cultural anthropology, the cultural side being divided correspondingly into branches dealing with material and with social aspects"—

But what I intend to say is this that the museological aspect of anthropology would naturally form a co-ordinating factor between the physical and the cultural sides. From two aspects museology can be observed which I wish to point out to you today.

- (1) Study of museology for its own sake—i.e. for the light it would throw on the present, past and future histories of mankind and should be a legitimate branch of anthropological study.
- (2) Study of museology for the pursuit of knowledge in search of truth. These ultimately result in the practical application of anthropology to mankind.

Besides the importance of museology and its association with the anthropological study we have yet to see more of its importance in itself. We have a philosophical as well as practical basis that man has indeed since the remote past distinguished himself from other animals by the adoption of his material equipment. We should, therefore, be contented with the fact that by a study of museology the basis for judgement of a people's physical and cultural status in the scale of advancement can be thoroughly comprehended. Museology has got so intimate a connection with the physical and the social conditions of the people that they cannot be separated in anthropological studies. Museology has, therefore, a position on an equal footing as the other branches in the studies of anthropology are and it is more important to have a co-operation and co-ordination among all these connective branches of studies. All the aspects of museological study are, therefore, of value in national welfare. Our first five year plan is in full operation and the second one is in the offing. They envisage an all round development and growth in India. But unfortunately

the most important issue of museological study and research has been completely left out and ignored. So it is desirable that both the Central and the State governments should realise the necessity of starting courses of museological study in different Universities of India.

I am deeply conscious of the responsibility of speaking to you of museology which is a baby science, and the poet says:—

“The first brick if a mason lays untrue,
The wall to sky if built shall rise untrue.”

I have attempted to discuss the general outlines of museology and have ventured to offer for the consideration of the scientists, some suggestions for the future development of the science, so that the first stone be laid well and true. It is an ambitious task and I am fully conscious of its magnitude. I, therefore, crave the indulgence of the scientists and the general public in this modest pioneer attempt.

Learned friends, I would now like to conclude my humble address by expressing my sincere and heart-felt thanks to you all for giving me a patient hearing.

I am afraid my speech is “not much better than that noise or sound which musicians make while they are tuning their instruments so I have been content to tune the instrument of the Muses, that they may play that have better hands.”

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SECTION OF MEDICAL AND VETERINARY SCIENCES

President :—SUBODH MITRA, M.B. (Cal.), Dr. Med. (Berlin),
F.R.C.S. (Ed.), F.R.C.O.G., F.A.C.S., F.N.I,

PRESIDENTIAL ADDRESS

THE CANCER PROBLEM

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I

INTRODUCTION

One of the most urgent problems of the day is to fight cancer with knowledge. During the last half a century, remarkable progress has been made to reduce the incidence and mortality rate of many chronic diseases particularly of tuberculosis. This has stimulated the investigators on cancer to work more intensely and I am one of those optimists who believe that in no distant future the nature of cancer will be revealed, and the incidence and the mortality rate controlled. As it stands today, except in undeveloped tropical countries, cancer is No. 2 killer of human beings, No. 1 being the heart disease.

During the last 50 years, extensive and exhaustive investigations have been carried on from clinical and demographic points of view but fundamental researches through biological studies have been taken up not later than a quarter of a century ago. Research is always a co-operative enterprise. Ideas are born in individual minds but their formulation is influenced by a wide variety of contacts and their translation into practical reality is aided by the entire scientific community.

There are already more than 30000 papers published from different parts of the world dealing with various aspects of cancer research. One can trace from these voluminous literature, how the trend of researches is moving from the gross clinico-pathological aspect to the finer biological processes. The solution of every large problem depends on the correct application, step by step, of a number of correlated facts that lead to the final proof. This is the history of every scientific achievement. The whole cancer problem is so complex that the final solution will probably come slowly through the gradual accumulation and integration of facts derived by co-operative efforts of a group of special investigators.

2

PREVALENCE OF CANCER IN INDIA

Assessment of the prevalence of a disease is not an easy task, specially for a vast country like India, having a population of nearly four hundred million extending over about 1·2 million square miles. Excepting a few principal cities, a greater part of the land is underdeveloped and the registration for vital statistics inadequate. Proper assessment is hardly possible without sampling studies of the whole population.

2.1 The incidence of cancer is usually deduced from hospital records, by way of admissions and autopsies as well as from total mortality figures in general. Clinical assessment is often vitiated by wide errors unless checked by biopsies which are not always possible. Autopsies will perhaps give a more correct information, but autopsies for 100 per cent death cases can never be possible. Even in an well organised country like Germany where the post mortem examination was obligatory in all the State hospitals, autopsies were made on an average of 4·3 per cent of the total death cases of the land (Lubarsch 1918). It was only possible for Prof. Müller, who had been nicknamed as "Cadaver Müller" of Jena to autopsy 90 per cent of the total deaths in Jena. Of course, Jena is a small town in Germany. Out of 5773 deaths above 20 years, 987 i.e. 17·1 per cent were found to be malignant (Fischer 1939). Dormans (1937) collected the biggest statistics records of autopsy cases from 42 German Pathological Institutes comprising 1,24,827 postmortemns. Malignancy was found in 22,139 cases i.e. 17·7 per cent.

2.2 Certain amount of work on cancer mortality in India has already been done. From the initial subjective opinion that, as compared to the European races, the Indian races were comparatively less susceptible to carcinoma, there has been a gradual shift; analysis of hospital and autopsy records and the reported causes of death in city population tend to show that the cancer mortality is not much lower in India than in the west (Vishwa Nath and Grewal 1935). But the picture is still far from definite.

2.3 Some investigations in the line were made by the author (Mitra and Das Gupta 1955) with the data from the city of Calcutta. The prevalence has been broadly equated to fatality to cancer. Before dealing with the death records of Calcutta Corporation Area (on which this note mainly relies), a passing mention may as well be made of other relevant data collected for this purpose. For example, out of total 9130 deaths occurring among the in-patients of the Calcutta Medical College Hospital during 1946-50, only 249 deaths (or 2·7 per cent) were caused by cancer; the annual rate of cancer deaths in the Hospital actually varied between 2·2 per cent (1942) and 3·8 per cent (1943) during this period. Autopsy

records of the same Hospital for the same period disclosed only 11 cancer deaths out of 549 total cases, giving about 2 per cent cancer mortality. Autopsy records of Rogers (1925) from the same hospital showed 4.59 per cent cancer mortality. Data were collected from a few insurance companies in India and the cancer mortality was seen to vary between 2 and 3.5 per cent among the assured lived. These total measures of mortality are however of little validity or use for comparative study: they are besides based on highly select and rather scanty material. Vishwa Nath and Grewal (1935, 1936) from collected autopsy records of different parts of India and Burma found the cancer mortality rate at 4.2 per cent. Khanolkar (1945) had 4.41 per cent from the Bombay K.E.M. Hospital autopsy records. The percentages given by both Vishwa Nath et al and Khanolkar are to be considered as *relative* cancer mortality figures as they eliminated deaths due to infectious and tropical diseases from the total number of deaths. This corrected cancer mortality compares favourably with the mortality rates in England and America.

2.4 To enable better assessment and comparisons, the total deaths (32,113 in number) registered with Calcutta Corporation in 1954 were examined in detail. The proportion of uncertified deaths was very low, less than 2 per cent of the total deaths in Calcutta. This was a distinct advantage. Khanolkar (1945) was in the unenviable position of having only about 38 per cent of this deaths certified by persons 'who had any acquaintance with medicine'. He accordingly inflated the cancer deaths 2.66 times on the assumption that the proportion of cancer deaths would be the same in the uncertified group. It is however not unlikely that a greater proportion of the cancer deaths might have been certified and an assumption that leads to inflation of numbers 2.66 times appears fortuitous.

The reported cancer deaths were scrutinised from the Corporation Death Registers before adopting corrected figures: the uncertified deaths were also similarly checked up. Table (1) shows the rate per cent of cancer deaths, that is, cancer deaths per hundred deaths from all causes, in each of the sex-age groups. The percentage distribution of the deaths from all causes in the respective sex-age groups is also shown (within round brackets) in Table (1). The cancer mortality of Calcutta Corporation appeared to be about 2.4 per cent of total mortality: the relative mortality from cancer was very little below age 20, increased gradually (with an earlier rise for women) to reach the maximum in age group 50-59 and declined slightly beyond that. The maximum was for women aged 50-59, a little less than 10 per cent of the total mortality.

2.5 People at large will be more interested in knowing his own chances of escaping or dying of cancer than in the mean annual mortality from it. Table (2) shows for persons at various ages the probability of death from cancer in course of their future life-time. The probability of death from all causes in future life-time is incidentally "unity for any person". These are worked out on the assumption that the persons were subject to 1951 Census West Bengal Life Table general mortality and had Calcutta 1954 cancer mortality. The probability was only about 2.5 per cent at birth, but increased to over 6 per cent at ages 40-60 to decline slightly after that.

Considering the fact that for the assessment of cancer mortality there are diagnostic errors ranging from 25 to 40 per cent even in Germany, England and America (Wells 1923) and much more so in India, it can be assumed that the incidence of cancer in India is on par with the incidence in Western countries. This prevalence in India will be

more manifested with the improved methods of diagnosis, larger number of autopsies and the better technic of recording the vital statistics. Any differences, apparent as they are, can be made good with a greater uniformity of age composition of the population. It can be further assumed that the incidence of cancer in India will be augmented with the increased longevity of the population as has been found in Vienna, where between 1923 and 1933, the number of persons over 60 was augmented by 40 per cent and the cancer death rate by 33 per cent (Overling 1944).

2.6 Is there any *racial susceptibility to cancer*? The idea of racial susceptibility came into vogue from the unequal distribution of cancer in various parts of the body amongst different communities. For example, cancer of the penis is unknown or rarest among Jews, rare among Mohamedans (2.9 per cent) but very common among Hindus (26.7 per cent), (Kennaway and Kennaway 1937). Primary cancer of the liver is a rare disease in England and America but constitutes of 90.5 per cent of all cases of cancer amongst the Bantu labourers of South Africa (Kennaway 1944). Cancer of the cervix is very rare in Jews specially in Jewish nuns and also said to be rare among Mohamedan women. From an exhaustive inquiry by Vishwa Nath and Grewal (1935) it transpired that cancer of the genital organs in the Punjab is 63.6 per cent among Hindus against 37.1 per cent among Muslims, and in Bihar and Orissa, the incidence is the same for two communities. The incidence of oral cancer is high in India. Figures given by Vishwa Nath (1935), Khanolkar (1945) and Mitra (1955) are 13.1 per cent, 22.5 per cent and 19.1 per cent respectively against 3 per cent in Western countries (Fisher 1939). Incidence of oral cancer rises with the habit of chewing betel leaf in the population. The Punjab where the habit is indulged only to a small extent has the least amount of oral cancer (5.4%); Delhi comes next (11.1%); Bihar and Orissa heads the list (26.7%) (Vishwa Nath 1935). It is probably not the betel leaf but the tobacco and unslaked lime in the quid which act as irritants. It appears that the environment, habits, customs and social status influence the differentiation of cancer in different sites among different people and communities.

The adjoining histogram shows the comparative incidence of cancer of different sites in two different places, Chittaranjan Cancer Hospital, Calcutta and Royal Cancer Hospital, London. The preponderance of oral, cervical and laryngeal cancer in India is very prominent (Vide Histogram).

3

IS CANCER HEREDITARY?

This question is often asked because there is a general apprehension amongst the public and particularly amongst those who have lost one or more of their relatives through cancer. Besides, the study of heredity in its relation to cancer is important to establish the exact position of heredity in the chain of circumstances that leads to malignant growth.

3.1 The most essential thing to settle the question of heredity is to have genetically pure strains. Hence experimental approach with mouse cancer was found most appropriate. It requires infinite pains to found a line that is genetically pure. Maud Slye (1914) took the initiative by selecting consanguine mates and letting them breed for generation after generation until after more than 30 generations, genetic identity

(homozygosity) was attained. Such strains may be called physiological monstrosities (Leo Loeb 1908) for they are creations of man and their like cannot be found in nature. But they are indispensable tools for analysing hereditary characteristics.

Enormous patience, perseverance and rigid vigilance are required to carry out this experiment. It is essential to keep all the animals, make all the crosses and hold all the issues for observation until the death of the parents from natural causes. Even after the natural death, both the parents have to be autopsied. Only those of the descendents have to be retained for further breeding whose parents had cancer. The mice must be housed under ideal sanitary conditions and constantly guarded against disease or accident to prevent early deaths. If an animal were to die prematurely all the descendents would be useless since there would be no way of determining whether or not it would have developed a tumour had it lived on into the cancer age. Even a single error in a crossing may ruin several years' work.

3.2 Working with this carefully created pure strain, it has been shown beyond any doubt that certain cancers like those of the mamma, the liver and the lung are associated with hereditary factors and appear with known frequency (Maud Slye 1922, Little 1936, Lynch 1924, Strong 1946 and Murray 1911). It has been further worked out that in the whole and varied process of experimentation nothing appears that might be called a "cancer factor" either in the form of a gene, a combination of genes or a gene mutation that would lead infallibly to cancer. What is transmitted is not cancer but merely a susceptibility to it, a constitutional factor.

3.3 Our knowledge of human transmission must necessarily be imperfect as it is impossible to carry on experimental investigations under ideal conditions created for the inbred mice. Even the incidence of mammary cancer in mice will not be as high under natural conditions as it would be where all environmental differences have been reduced to the minimum.

Nevertheless, there is enough suggestive evidence that hereditary factors have some bearing on human cancer. Characteristic racial incidence of cancer at the various sites is well known. Iguchi (1932) reports a relatively low incidence of mammary cancer in Japanese women. The Norwegian Cancer Committee collected 6000 cases of cancer and interviewed their relatives. The incidence of cancer was found higher among sisters than wives of cancer patients (Waalder 1931). If one parent had cancer, more than twice as many of the siblings had cancer as when neither parent was affected (Waalder 1931).

3.3.1 Retinoblastoma is an inherited disease at times, usually appearing in successive generations (Weller 1941). Neurofibromatosis appears in families and in many is inherited in the manner of a dominant character. Rectal polyps often undergo malignant degeneration and often inherited in a dominant fashion (Lockhart-Mummery and Duker 1939, Burdette 1948). Paulsel (1924) reports about two 'cancer families'. In the first, the father, mother and 6 children died of cancer of the stomach, the only member to escape the disease was lost in an accident at the age of 28 years. In the second family, the mother and 6 children succumbed to cancer of the stomach, and the father was supposed to have died of cancer of the stomach too.

3.3.2 Such facts as these apparently look impressive, but care must be taken not to attribute to 'cancer families' more importance than they deserve. For a disease as common as cancer there will be, just by chance,

an accumulation of cases in some families and a total absence in others, quite apart from any question of heredity.

3.3.3 Attempts have been made to study the frequency of cancer amongst the ancestors of the cancer patients. This method conceals many sources of error as the data collected have been influenced by subjective factors, the investigators having nothing to fall back upon except the symptoms reported to them. The results of such inquiries show anywhere from 2 to 30 per cent of cancerous antecedents among cancer patients. So divergent are the results, that they are utilised both for and against the hereditary influences in the genesis of human cancer (Oberling 1952).

3.4 As has been stated above, the influence of environment cannot be overlooked even in the mouse strain. It is certainly more so in human cancer. Uniovular twins furnish a ready means in assessing its real value. These twins are identical from a genetic point of view and they behave as two members of a genetically pure strain of mice. If heredity has got anything to do with the genesis of human cancer, the same neoplasms should regularly be found in twins. According to Versluys (1935), the number of identical tumours hardly exceeds 30 per cent and in the opinion of some others this figure is far too high (Oberling 1952). This hardly meets anticipation and shows the great importance of external influences that have no connection whatsoever with heredity.

"For him who walks in the valley of the shadow this should be a consoling thought. Even were he certain, from a genetic point of view, to die of cancer, the truth is that he has a 70 per cent chance of escaping and ending his days in some other manner" (Oberling 1952).

4

CELL MORPHOLOGY AND CELL BIOLOGY

It has already been fully established that a cancer cell is quite distinct from a normal cell. Recent studies with the help of modern appliances of electronmicroscopy, X-ray and u.v. microspectrophotometry, radioactive isotopes tagging and chromatography—definitely indicate distinct biophysical, chemical, biochemical and genetic changes characteristic of cancer cells. The cancer biochemists and cancer enzymologists of to-day have at their command these tools for elaborate recording and measuring devices. As new concepts come to hand about the great fundamental cancer problems, namely, the nature of mutation, the mechanism of cell division and nucleic acid replication, the chemistry of chromatin and the nature of 'cods' in genetic material, the genetic control of metabolism, the mode of action of virus, bacteriophage and transforming principle—the present urge for cancer research is such that the new knowledge is immediately applied to the cancer problem.

As an enormous volume of work has been done in this direction, a brief outline of the most recent studies of cancer cells vis-a-vis normal cells have been given here in the form of tables (3, 4, 5, 6, 7, 8 and 9).

4.1 *Morphologically*, the cell wall, cytoplasmic volume, ergastoplasm, mitochondria, Golgi material, nucleus, nuclear membrane, nucleoli and chromosomes have got distinctive and characteristic features for cancer cells. Tissue chemistry as elaborated by Cowdry (1949) shows an *increase of 50 per cent or more* of Lipid phosphorus: dry weight ratio, succinic dehydrogenase activity, adenylypyrophosphatase activity, arginase activity, lysine, tryptophane and isoleucine; *an increase of less than 50*

per cent of water content, choline, leucine, methionine, valine, phenylalanine and threonine, *no change* of ascorbic acid : NP ratio, specific activity of p^{32} in phospholipid fraction, inositol, histidine, glutamic acid, cystine and arginine ; *a decrease of less than 50 per cent* of Potassium : NP ratio, Sodium : NP ratio, Magnesium : NP ratio, Cytochrome Oxidase, DNA, Cytochrome C, Paraminobenzoic acid, Vit B₆ Complex and *a decrease of more than 50 per cent* of Calcium : NP ratio, Iron : NP ratio, Copper : NP ratio, Zinc : NP ratio, NPN, Urea, Ammonia, total free amino acids, Biotin, Ca⁴⁵ uptake and retention and free calcium. Biophysically the mean extinction values of nucleoproteins and total proteins as expressed by C²⁶⁵ and C²⁸⁰ (Table 7) have been found to be much higher in cancer cells by Moberger (1954).

4.2 The distinctive biological phases of cancer cells corresponding to normal cells have been studied from the stratified squamous epithelia of normal cervix and the epidermoid carcinoma of the cervix in our Chittaranjan Cancer Hospital laboratory (Mitra and De, 1954). It will be evident from the table 9 that in the preparatory phase (which is a combined resting and mitotic phase) there is a preponderance of cancer cells ($89.01 \pm 0.20\%$) corresponding to normal cells ($49.53 \pm 0.55\%$) in the same phase. Cellular population not coming to maturity is significant : it is $85.00 \pm 0.23\%$ in cancer cells against $1.36 \pm 1.10\%$ in normal cells. The striking phenomenon has been found as regards *retention* in the preparatory phase : it is 77.84% in cancer cells against 0.0% in normal cells.

Now the question is : Why is such a preponderingly high percentage of retention in the preparatory phase of cancer cells? Is it due to an imbalance in the enzymic activity or to the loss of Potter's strategic enzyme?

5

METABOLISM IN CANCER CELLS

Since the pioneering work of Otto Warburg (1923) on enzymes and cancer, attention has been focussed in this direction. His hypothesis that tumour tissue, in contrast to normal tissue is characterised by a distinctive metabolic pattern has achieved a great momentum through the modern investigators of cancer problems.

5.1 *Aerobic Glycolysis* : Warburg observed that slices of tumours possessed a high rate of aerobic glycolysis. Dickens and Simer (1930) showed that tumour tissue, unlike most normal tissues with a high rate of anaerobic glycolysis, usually has a low respiratory quotient. A high rate of glycolysis *in vivo* and *in vitro* was shown by the Coris (1925), who determined the concentration of lactic acid in the blood from the wing of a chicken bearing a sarcoma. Direct determinations of the concentration of lactic acid in tumours *in vivo* were made by Le Page (1948). It has been pointed out by Berenblum *et al* (1940) that although a high rate of aerobic and anaerobic glycolysis is common to most tumours, it is also found in many normal tissues, such as retina (Warburg 1930), kidney medulla, jejunal mucosa (Dickens *et al*, 1936, 1941) and myeloid cells of bone marrow (Waren 1943). Hence it cannot be a distinctive characteristic of cancer. Further, some tumour tissues have little or no aerobic glycolysis (Crabtree, 1929 ; Murphy and Hawkins, 1925).

5.2 *Oxidation* : Although it is known that tumour tissue possesses a full complement of oxidative enzymes, experiments with homeogenate preparations may be interpreted as showing that tumour tissue manifests

a reduced capacity for oxidation (Olson 1951). According to Potter (1951), the capacity for oxidation of most tumours is much lower than that of liver, kidney, heart or brain. It is of the same order of magnitude as that found for spleen, thymus, lung or embryonic tissue.

One of the most characteristic properties of an homogenate is that it is not homogeneous. By following the technique of differential centrifugation Schneider and Hogeboom (1951) have shown that neither the nucleus (containing DNA) nor the microsomes (containing RNA) is active in the breakdown of carbohydrates. The metabolic picture of a cancer cell is one of extreme glycolytic activity in cytoplasmic sap and of moderate oxidation in the mitochondria. It has been suggested that the relation may be due to the poor binding of the coenzyme, diphospho-pyridine nucleotide, by the mitochondria of tumour tissue (Wenner and Weinhouse 1953).

5.3 Other Enzymes : That rapid and uncontrolled growth of a tumour indicates active protein synthesis has been demonstrated by isotope experiments *in vitro* by Zamecnik et al (1951) and *in vivo* by Tyner et al (1953).

Isotope experiments carried out both *in vivo* and *in vitro* have shown that nucleic acid metabolism is very active in tumour tissues (Heidelberger, 1953).

The incorporation of labeled acetate or glucose into the fatty acids of tumour slices is not excessive, suggesting that the lipid needs of a rapidly growing tumour are supplied preformed from the host (Medes et al, 1953).

In general, tumours have a lower range of enzyme activity and a characteristic pattern of activity for tumour tissue just as there is a characteristic pattern of enzyme activity for each particular normal tissue. This pattern is independent of age, rate of growth or origin of the tumour whether spontaneous, transplanted or induced (Greenstein 1954).

5.4 Alternative Metabolic Pathways : Besides major metabolic pathways as Emden-Meyerhof scheme of phosphorylating glycolysis and the Krebs tricarboxylic acid cycle, many alternative metabolic pathways have been discovered by recent studies with isotopes (Potter and Heidelberger 1950). Thus a labeled carbon atom in a molecule of glucose may find its way not only in glycogen or respiratory CO_2 , but also into other substances, such as fatty acids, aceto-acetic acid, cholesterol, nucleic acid, ascorbic acid or many other (Potter 1944).

5.4.1 Alternative pathways determine the metabolic differences between individual differentiated tissues. They also make possible the control and integration of metabolic activity although the precise mechanism is not known. Many possibilities exist, including changes in the amount, activity and intracellular distribution of enzymes, coenzymes, activators and antimetabolites (Rossiter, 1955). In various regions of the cell, one can envisage competition among substrates for certain enzymes and similar competition among enzymes for substrates, coenzymes, activators and antimetabolites also may be involved in these competitions. The over-all process is modified by conditions superimposed by genetic, hormonal or other activity.

5.4.2 Potter (1950, 1951) has shown that in cancer tissue, some of the alternative metabolic pathways are far from subsidiary, and the factors controlling the alternative pathways and the rate limiting mechanisms of the over-all metabolism of tumour tissue differ from those of normal tissue. In normal tissue, which is not carrying out tricarboxylic acid cycle oxidation to capacity, the metabolism may be controlled by such known rate-limiting factors as the concentration of substrate, the concentration of inorganic phosphate, or the concentration of phosphate acceptor. In

tumour tissue, on the other hand, the non-availability of oxidative enzymes may be the prevailing rate-limiting mechanism. This would cause an increase in the availability of the intermediates of glycolysis. Thus, in cancer, many of the glycolysis metabolites ("the building blocks of growth") are not oxidised as fuel, but are deviated into alternative pathways, such as protein synthesis, nucleic acid synthesis, or some other metabolic activity characteristic of uncontrolled growth of tumour tissue.

5.5 Anti-metabolites : Anti-metabolites play an important role in biologically directing metabolism. They also provide a means whereby metabolic processes may be controlled from without. It may be possible by the skilful use of anti-metabolites to divert a metabolite from one metabolic pathway to an alternative pathway.

5.5.1 Both D-glucosamine and glucose can be phosphorylated in the presence of A.T.P. The glucosamine competes with glucose for the enzyme hexokinase. It has been suggested that the phenomenon of autonomous growth in cancer tissue is considered to be the result of a permanent imbalance between (a) enzymes that utilise essential metabolites in the growth process and (b) enzymes that convert these metabolites to pathways not involved in growth (Schmitz, Potter and Hurlbert, 1954). This imbalance may be effected by the loss of an enzyme, a strategic enzyme, which is essential for the control of normal growth (Harpur and Quastel, 1949). Since the phosphorylation of glucosamine diverts A.T.P. from possible use in other metabolic pathways, Quastel and Cantero (1953) made the interesting suggestion that D-glucosamine might modify the metabolism of tumour tissue.

6

NATURE OF CANCER

6.1 Cancer cell is an altered normal cell. Bullough (1950) has shown that a high mitotic rate is associated with high tumour yield. Epithelia of the vagina, uterus and rectum are highly active mitotically and so most liable to develop cancer. Mitotically inert tissues like striped muscles and brain rarely develop cancer. Exceptions are encountered in the duodenal mucosa with high mitotic rate but low tumour yield and mammary gland with low mitotic rate but high tumour yield.

6.2 Stroma of the normal tissue also undergoes changes in the process of carcinogenesis. Woodhouse and Billingham (1950) have demonstrated that carcinogen-treated epidermis and thin Thierschgrafts of carcinogen-treated skin did not yield tumours when transplanted orthotopically to untreated body sites. On the other hand, tumours have been obtained when a denuded carcinogen-treated area was resurfaced with untreated epidermis. Hence it can be deduced that the effective carcinogenic action of methylchloranthene is not limited to the epithelium itself but also extends in the deeper tissues.

6.3 There are two biological phases of carcinogenesis. First there is the specific irreversible initiating phase, in which normal cells are converted to latent tumour cells that lie dormant until stimulated in the Second Phase (promoting phase) to become morphological tumours. The promoting phase can be brought about by non-carcinogenic procedures such as application of croton oil (Berenblum and Shubik 1947).

6.4 During the early stage of carcinogenesis, the mitotic cells increase from about 17 to 150 per 15,000 cells (Cooper and Reller 1942). Simultaneously the number of cell layers increases about six times ; the cell volume

increased continuously from basal to the superficial layers (Cowdry and Palleta 1941).

6.5 The factors chiefly concerned with the process of carcinogenesis are genetic factors, hormonal factors, milk factor, age, diet and carcinogenic agents.

6.6 *Carcinogenic agents* : Carcinogens may be classified under different groups, namely, (a) Physical carcinogens, *e.g.* sunlight, ultra-violet rays, X-rays and radioactive substances ; (b) Chemical carcinogens, *e.g.* carcinogenic hydrocarbons, Azo-compounds, etc. ; (c) Physio-pathological carcinogens like hormones ; and (d) Biological carcinogens under which may be placed all the ill-defined agents like virus complex, genetic factor, milk factor, etc.

6.6.1 *Chemical Carcinogenic agents* : The first reference to chemically induced cancer was made by Percivall Pott in 1775. He discovered the cause of cancer of the scrotum as the contamination by soot amongst chimney sweeps. Nothing further was known about it for about a century till von Volkmann in 1875 described industrial cancer contracted through contact with coal tar, and in 1876 Bell discovered 'paraffin cancer' due to shale oil. Later, with the development of industries, many cases of tumour induction by mineral oil, tar or soot were described, notably 'mule spinners' cancer amongst cotton spinners, due to mineral oil used as a lubricant. It was left to Yamagiwa and Ichikawa of Japan to successfully induce malignant skin tumours in 1918 by applying coal tar on the ears of rabbits.

6.6.2 The polycyclic aromatic hydrocarbons and their heterocyclic analogues constitute the main class of tumour inducing compounds. A member of this group, 3:4 benzpyrene, occurs in coal tar ; another member, 20-methylcholanthrene, can be prepared from sterols and bile-acids—substances found in the human organism.

6.6.3 The mechanism of the action of carcinogens have not yet been fully clarified. They probably enter the cells through the cell membrane. It is not known whether the action depends on size and shape of the molecule or due to selective adsorption. Bergmann (1942) postulates an acceptor within the cell to which molecule of a requisite optimal size and shape are adsorbed.

6.6.4 From Berenblum and Shubik's (1947) experiments it is found that two agents are required for tumour induction, namely, the specific carcinogen for the initiating action (initiator) and the non-specific irritant for the promoting action (promoter).

6.6.5 Fieser (1945) suggested a reaction of the hydrocarbon whereby an -S-S linkage of a protein or peptide molecule is broken, giving rise to a free sulphhydryl group, -SH, on the one hand, and a hydrocarbon-peptide link, >C-S-, on the other. Fieser is of opinion that the hydrocarbon becomes attached to a protein constituent of the cytoplasm rather than forms a complex freely soluble in the blood stream. This suggestion has been supported by Crabtree (1945), who postulated that these compounds, by preferential metabolism and excretion, interfered with those cell constituents bearing -SH groups with which the carcinogen has to combine in order to act. Crabtree found that compounds as closely related to the carcinogens as the hydrocarbons anthracene and phenanthrene (both excreted as mercapturates) can act as inhibition, and suggests a competition reactive for an -SH group containing enzyme or other cell constituent, which might take place between the inhibitor and the carcinogen.

6.6.6 An attempt has been made to deal with the problem by a more basic method than the study of common chemical properties. Pullman and Pullman (1946) attempted to find a common, general and fundamental

property for all chemical carcinogens, which might then disclose the common mechanism for carcinogenesis. Whether the relationships discovered are significant or not remains yet undecided, but the approach used is so startlingly fresh and original, and the method of so fundamental a character that it opens the gates to a flood of new ideas.

Pullman and Pullman used the methods of wave-mechanics and in particular the concept of resonance to determine the electron structure and calculate the densities of free electrons at each carbon atom and each bond of carcinogen molecule. In the types of structure possessing carcinogenic activity there exists a region of high activity (great density of free electrons) at two neighbouring atoms and the bond connecting them. This region is found at what they term 'region K', or the so-called phenanthrene double bond.

The Pullmans found, through their calculations, that on substitution of methyl groups in certain positions, the relative electron density at 'region K' increases. At this point arises the startling correspondence between electron density as calculated and carcinogenic potency as observed. After having evaluated the electron densities at 'region K' for various types, it appeared that active compounds showed values above, and inactive compounds values below a certain threshold; further, the values are in agreement with the degree of carcinogenicity.

The Pullmans' work is important as it relates for the first time numerical values for chemical reactivity to carcinogenicity and, quite generally, establishes the first bond between a branch of chemistry as mathematical as wave mechanism and a biological phenomenon such as cancer. According to Coulson (1953): "The whole field is a singularly interesting one, because it represents one of the very first serious attempts to relate what are obviously complex biological phenomena to quantum-mechanical principles. Its significance has not only in the fact that carcinogenic potency (or otherwise) has been correctly predicted on purely theoretical grounds for quite a large number of molecules, which had not, at that time, been investigated experimentally, but also in the fact that it opens up new fields of inquiry and discovery and itself suggests new interpretations: this must inevitably lead to a better understanding of such phenomena as carcinogenesis, drug action, chemical mutations and the mechanism of oestrogenic and other hormonal activity." It is quite likely that in no distant future, enormous and far reaching developments in these fields would be forthcoming.

6.7 *Genetic factors* have to a certain extent been discussed along with heredity.

Three different lines of investigations viz., (1) experimental production of cancer, (2) study of spontaneous tumours and (3) the study of transplantable tumours enlighten as about the genetic factor.

6.7.1 Lynch (1933) reported that different genetic strains of mice showed different degrees of reaction to tar-induced skin carcinoma. It was also shown that these genetic differences depend on multiple Mendelian factors. Kreyberg (1935) showed that a strain of mice having a high incidence of spontaneous breast cancer has a lower frequency of induced cancer than another strain with no spontaneous breast cancer, showing thereby that the different types of malignancies have different genetic basis. Similar results were also reported by Branch (1936) in 1:2:5:6 dibenzanthracene induced sarcomas in mice. The dibenzanthracene induced tumours were also shown to be strain and organ specific or, in other words, the different types of tumours grow only in animals of specific strain in which they originated. More detailed genetic studies

(Heston 1940) on the susceptibility of dibenzanthracene induced lung tumours in different strains of mice showed that tumour susceptibility is dominant over non-tumour and that susceptibility may also be influenced by non-genetic factors.

6.7.2 Strong (1945) was able to induce coat colour mutations in mice by treating them with 20-methylchloranthene. He discussed the possibility that through an analogous process, the same chemical may induce somatic mutation and thus give rise to malignancy. He later (1945) reported two germinal mutations with the chemical and showed that the two new strains developed from these mutants have different susceptibility to experimental induction of tumours.

6.7.3 The second line of investigation is the use of spontaneous tumour. Bittner (1936) has shown that extra-chromosomal influences are also operative in the production of breast cancer in mice. Details have been given in the chapter on heredity. Hereditary factors rather than extra-chromosomal influences largely determine the susceptibility of other types of spontaneous tumours such as lung tumour, leukaemia, liver tumours, stomach tumours, etc.

6.7.4 The third line of approach is through the study of transplantable tumours. It has been established by Little (1947) and others that there is a genetic basis of susceptibility (S) and resistance (R) to transplants. When a susceptible strain is crossed with resistant strain, the F_1 hybrids show susceptibility. When F_1 is back crossed to S parent, the progeny is also susceptible but if the F_1 is crossed with the R parent both S and R individuals are produced. The F_2 obtained by crossing two F_1 individuals similarly develop both kinds of progeny.

6.7.5 It is thus found that genetics has a dual role to play in explaining the process of carcinogenesis. Mutation of the gene located in the somatic cells, according to many, is the immediate basis of the initiation of cancerous growth of these cells. There are also evidences to show that the somatic mutation is in its turn controlled to a certain extent by the gene complex located in the germ cells of the organism.

6.8 *Hormonal factor*: If a potentiality for cancer exists, a suitable endocrine environment may accelerate or promote that potentiality or on the other hand, prevent its expression. The possibility that abnormal endocrine environments can create or destroy cancer seems remote. There is no proof that they are the direct causes of cancer.

In this connection, oestrogenic, progestational, androgenic, adrenal cortical hormones and certain hormones of the pituitary are concerned.

6.8.1 The mammary tumours occur in 90% or more of female mice of some inbred strains; they rarely, if ever, occur in males. The incidence of the mammary tumours among breeding female mice of most strains is significantly higher than among virgins of the same stock. The Strong A strain shows the greatest difference in incidence of the mammary tumours among breeding females (83.6%) and virgins (4.9%) (Bittner 1939). The incidence of the mammary tumours in virgin mice of the A strain is increased by oestrogen administration (Gardner 1939).

6.8.2 The low incidence of tumours in virgin mice of the A strain is genetically determined. Reciprocal hybrids between the A and C_3H strains both show a high incidence of tumours among the virgins, approaching that of the C_3H strain. On the assumption that a high incidence of tumours in virgin mice is hormonally determined, the term "inherited hormonal influence" has been applied (Bittner 1948).

6.8.3 Lathrop and Loeb (1916) observed that in mice with a mammary tumour incidence of 60 to 70%, ovariectomy at or before the age of 3 months completely or almost completely prevented the appearance of mammary tumours, at the age of 6 months reduced the incidence to 9% while ovariectomy after 7 months of age had little effect on the incidence of the mammary tumours.

6.8.4 The appearance of breast cancer in women following oestrogen administration is difficult to interpret. Hormonal factors in ovarian tumorigenesis has been reported by Biskind and Biskind (1944). Granulosa cell tumours developed within 11 months in ovariectomised rats of the Sherman strain bearing intrasplenic ovarian grafts.

6.8.5 Adrenocortical carcinoma developed in mice of inbred strain (CE) subsequent to castration at birth or within one or two days thereafter; all of the females when 6 months old and most of the males when 7 months old had such tumours (Woolley and Little 1945). They produced either oestrogenic or androgenic responses in their hosts. The tumours were prevented when castrated mice received adequate amounts of stilbesterol.

6.8.6 Tumours in castrated mice of the Bagg albino strain produced predominantly oestrogen, those in the mice of C₃H and CBA strains elaborated both oestrogen and androgen and those of the A strain only androgen (Frantz and Kirschbaum 1949).

Tumours of different types, namely, sarcomas, lymphoid tumours and adenocarcinomas have also been produced by prolonged administration of pituitary growth hormone (Moon et al 1950). Korteweg and Thomas (1939) found that papillomas and carcinomas arising in hypophysectomised mice painted with a solution of 3,4-benzpyrene occurred at a much later age than in the intact controls similarly treated.

6.9 *The Virus Complex*: Since the beginning of this century, Borrel (1903) conceived the idea of the viral origin of cancer. This theory did not have any support from the scientific world until Peyton Rous (1911) successfully grafted the breast sarcoma of a Plymouth Rock hen by inoculation of tumour filtrates. During this period Fujinami and Inamoto in Japan reported a Myxosarcoma of the fowl possessing analogous properties. These transmission experiments with cell free filtrates of tumours yielded the first positive evidence in support of the virus theory.

6.9.1 Two criticisms were labelled at his work, namely, the resultant masses were granulomatous and not neoplastic, while the second point was that it had only been accomplished in birds and had no mammalian counterpart.

6.9.2 Shope (1933), however, found the papilloma in the American cottontail rabbit, due to a filter-passing virus, which also had the power to induce similar tumours in domestic rabbits; and these almost inevitably, after a lapse of one or two years, became frank squamous cell carcinomas with metastases. It was reported in 1938 by Lucke that a spontaneous renal adenocarcinoma in the leopard frog (*Rana pipiens*) was probably caused by a virus. It is transmissible after long storage in glycerine and produces an adenocarcinoma, not at the site of inoculation but only in the kidneys.

6.9.3 Hamzaki et al (1953) had succeeded in isolating the virus HST from Yoshida's ascitis tumour. The antisera produced by the above virus actually inhibited the growth of the ascitis tumour which however regained their malignant characteristics when the virus in question was re-introduced.

6.9.4 *Milk Factor* : Maud Slye (1913) showed that strains of mice could be separated which could show either a very high or a very low incidence of mammary cancer. In 1936 Bittner showed that the extra-chromosomal factor was transmitted by the mother's milk. By fostering mice of the "cancer" strains on "non-cancer" mothers, the cancer incidence could be reduced from 97.4 per cent for C₃H mice to 1.9 per cent in ten generations. Andervont (1945) obtained the complete elimination of mammary cancer in C₃H mice in five generations by removing the animals from the uterus by caesarean section and fostering them upon C₅₇ mice free from cancer. Conversely, the frequency of cancer in the latter line was raised from 9 to 70 per cent by fostering them upon mothers of the cancer line. It is now established that there are at least three factors operative in the production of mammary carcinoma in mice, namely, a milk factor transferred during nursing, hormonal stimulation of the mammary gland and an inherited susceptibility by the males and females of a high cancer strain.

6.9.5 In spite of meticulous investigations, it was not possible to recover any virus from human tumours.

De Witt Fox (1951), however, observed virus like bodies in human cancer. He made an electron micrograph study of normal and tumour tissue after disruption of the cell membrane by homogenisation in a Warburg microblender and ultracentrifugation through the Berkefield filter. Virus like bodies (60-230 m μ in diameter) were found in tumour tissues (both malignant and benign) but none in the normal tissue.

6.9.6 The transmissible agents in the filtrates are characterised by : submicroscopic particles, (size varying 60 to 230 m μ in different species), a medium resistance to heating, being inactivated at 55°-60°C ; a great sensitivity to oxidation, being reactivated by some reducing agents ; a stability in a frozen or dry state ; and a remarkable resistance to glycerol and to X-rays. Analysis of the sediment by highspeed centrifugation shows a complex structure containing lipoid, carbohydrates and nucleoprotein of the ribose type (Claude, 1947). DNA are found only in higher viruses (Hourowitz, 1950).

The viruses of avian leukoses and tumours are antigenic for both heterologous and homologous species. These particles exhibit marked cytotropism and a power of adaptation, remain latent in suitable host cells and have a propensity to mutation depending on the age and the species of the host (Duran-Reynals, 1946). Avian sarcoma agent exhibits pleomorphism in its passage through different hosts. These filterable avian agents differ from all other carcinogenic agents in that they can induce the precise kinds of tumours as those from which they arise and they multiply only in the tumours which they originate. These agents are demonstrable only in the mesenchymal tissues and not in epithelial tumours in birds. Hence the point in question is whether this agent or the virus can be considered as prototypes of all malignant tumours in all animals including man.

6.9.7 *Discussion on Virus theory* : Unfortunately for the theory of continuing virus activity as a cause of malignancy, virus can be recovered with ease from the simple growth, but only with difficulty from the carcinoma, although immunity reaction would suggest its continued presence (Scarff, 1951). Gye (1949) hoped that he had brought the virus point of view more into line with mammalian cancer when he succeeded in inducing tumours in mammals after freez-drying the transplanted tumour tissue at -79°C. He postulated that such transmission could only be by means of an infecting agent, but unfortunately it has since been shown that living

cells can survive such harsh treatment when the dried material is reconstituted in 5.3 per cent glucose solution or in 1 in 500 neutral solution of cysteine (Passey & Dmochowski, 1950) indicating that living cells, and not a virus, are responsible for the results. Passey et al (1950) has further shown that suspensions of sarcoma cells which have been frozen in glucose solutions and desiccated may show active growth *in vitro* after reconstitution in glucose.

As a matter of fact there are certain authors who would call the tumour viruses "viroids" (Altenburg 1946), "pro-virus" (Darlington and Mather, 1949) or a group having properties by which they can be differentiated from other viruses (Haddow, 1947, Kidd, 1950 and Rhoads, 1949). It is difficult to explain the phenomena of masked condition, where the virus occurs not in a corpuscular form but dissociated and attached to cell structures and the transmissibility of latent virus from one generation to another. It has been remarked that the narrow specificity of the agent, in the sense that it always reproduces the same tumour is unlike the behaviour of a real virus.

6.10 *Somatic Mutation*: The position of other neoplastic conditions where the presence of virus has not yet been proved is not yet clear. Here a new element is introduced, and the change of prime importance has been considered at the level of the self-duplicating unit of the affected cell. Many authors, such as Kill (1946), Haddow (1947) and Butenandt (1952) consider that autonomous multiplication of particles or "duplicants" or the autocatalytic production of some chemical substance in the interior of the cell may be the cause of the new property of autonomous growth acquired by the neoplastic cell. But what they cannot accept is the concept that these particles of chemicals can be of exogenous origin.

6.10.1 The origin of these autonomous particles was thought to be in the nucleus or in the cytoplasm. Graffi (1941) is of opinion that carcinogenic hydrocarbons get selectively attached to mitochondria which might undergo irreversible changes and acquire an ever-increasing degree of autonomy in their metabolic functions. This could continue until their functioning became completely emancipated and they would then be in all ways comparable with viruses. It has been pointed out by Zollinger (1950) that although carcinogenic hydrocarbons might get attached to mitochondria (since they are lipo-soluble), they also cause other disturbances, not least among chromosomes (Von Moellendorff, 1939); and in the chain of processes leading to cancer, the irreparable damage to chromosomes is certainly more important than alterations to mitochondria.

6.10.2 Haddow (1953) in his "newer interpretations of the biologic mechanism" suggests that "the primary step may be the inhibition of certain fundamental processes of genetic synthesis followed by the generation of new self-duplicating fibre or template, chemically, and hence genetically modified.

6.10.3 Caspersson (1947) has given an original interpretation to the possible significance of heterochromatin in the process of carcinogenesis with special methods of cytochemical analysis. Heterochromatin regulates the formation of protein and thus the primary growth process. This formation takes place with the mediation of nucleic acids which are of ribodessose type in the reproduction of the genes in the chromosome apparatus and of the ribose type in the protein formation of the cytoplasm. The formation of cytoplasmic proteins seems to be induced by a specific portion of the chromatin, the heterochromatin, which produces proteins of specific type. These proteins are collected in the nucleolus and make up its main

mass. From the nucleolus they wander towards the nuclear membrane where with the mediation of ribose nucleic acids there takes place the formation of cytoplasmic protein.

Between the malignant tumour cell and the normally growing cell there seems to exist a fundamental difference in regard to the development of the system of protein formation which provides the background for all growth and multiplication. In the malignant tumour cell the endocellular inhibitory mechanisms which normally limit the activity of the protein-forming system, have more or less ceased to function, thus leading to specific alterations in the cytochemical picture. These observations show that the heterochromatic section of the nucleus must play a very special role, not only in the growth of the cancer cell but also in carcinogenesis. Disturbances in the heterochromatic system seem to be a necessary prerequisite for the malignant growth (Caspersson and Santesson 1942).

6.10.4 Darlington and Thomas (1941) and Gulick (1944) are of opinion that heterochromatin appears to have a marked influence upon the supply of nucleic acid and that an oversupply of heterochromatic segments can accelerate the mitotic cycle.

Goldschmidt (1948) also expresses the view that heterochromatin may undergo a genetic change analogous to mutation in the euchromatin, the action being primarily concerned with the process of growth of chromosomes. Koller (1947) suggested a competition which 'comes into operation when the amount of nucleic supply is diminished at various levels': (a) intrachromosomal, when euchromatin competes with heterochromatin of the same chromosome, (b) interchromosomal when the whole chromosome or several chromosomes compete with each other, (c) intercellular when two or more adjacent cells compete with each other as in tumours, and (d) inter-tissues when cells of one tissue compete and have a greater demand for nucleic and supply than cells of other tissues. Koller thinks that the heterochromatin behaves as an indicator of metabolic conditions which prevail within the cell. It also functions as a regulator, being responsible for maintaining equilibrium of demand and supply for nucleic acid. The balance can be upset not only by external condition but also by internal factor such as by the addition of an extra heterochromatic chromosome to normal chromosome complex.

6.11 It has more or less been agreed that in the process of carcinogenesis, somatic mutation starts at the chromatin level, but some of the carcinogens are not mutagenic (Steiner 1954). The virus and mutation theories led to the chemical theories, all of which fail as yet to explain in terms of established concepts, the phenomena of cell multiplication stimulus and the failure of the body to stop the process. There is a comparatively recent concept of cancer as an artificial parthenogenetic somatic activation by diverse chemical and physical agents. According to this idea, a neoplasm represents essentially a growth composed of somatic cells, initiated by parthenogenetically competent stimuli; unlike a normal pregnancy the body has no physiological mechanism to stop the abnormal growth (Steiner 1954).

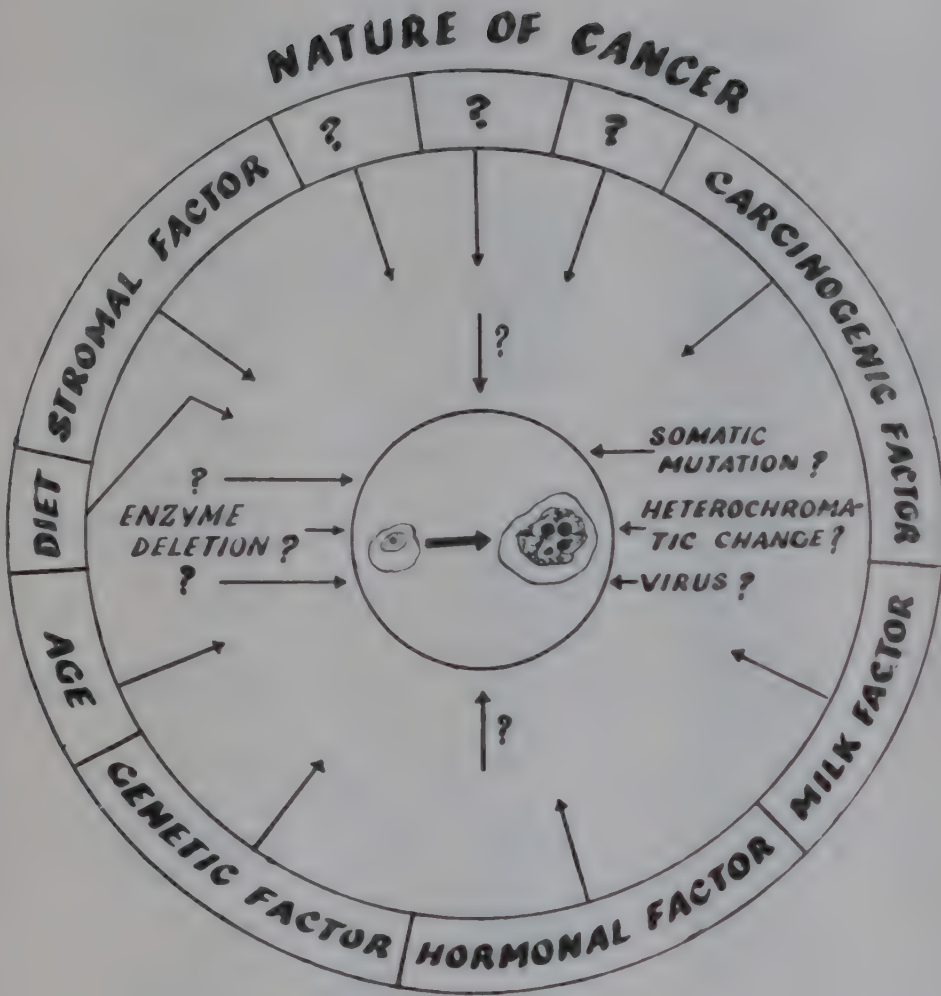
From the oncological point of view there has been a remarkable progress in the study of cancer problem from every angle of vision. It must at the same time be admitted that the core of the problem is still to be explored. As a result of extensive and all-embracing researches on cancer problem, newer brain waves are coming to the forefront opening alternative pathways and I am one of those optimists who believe that the normal philosophic and scientific mind will win over the abnormal matter.

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**A COMPARATIVE INCIDENCE OF CANCER
AT VARIOUS SITES: CALCUTTA - LONDON.**

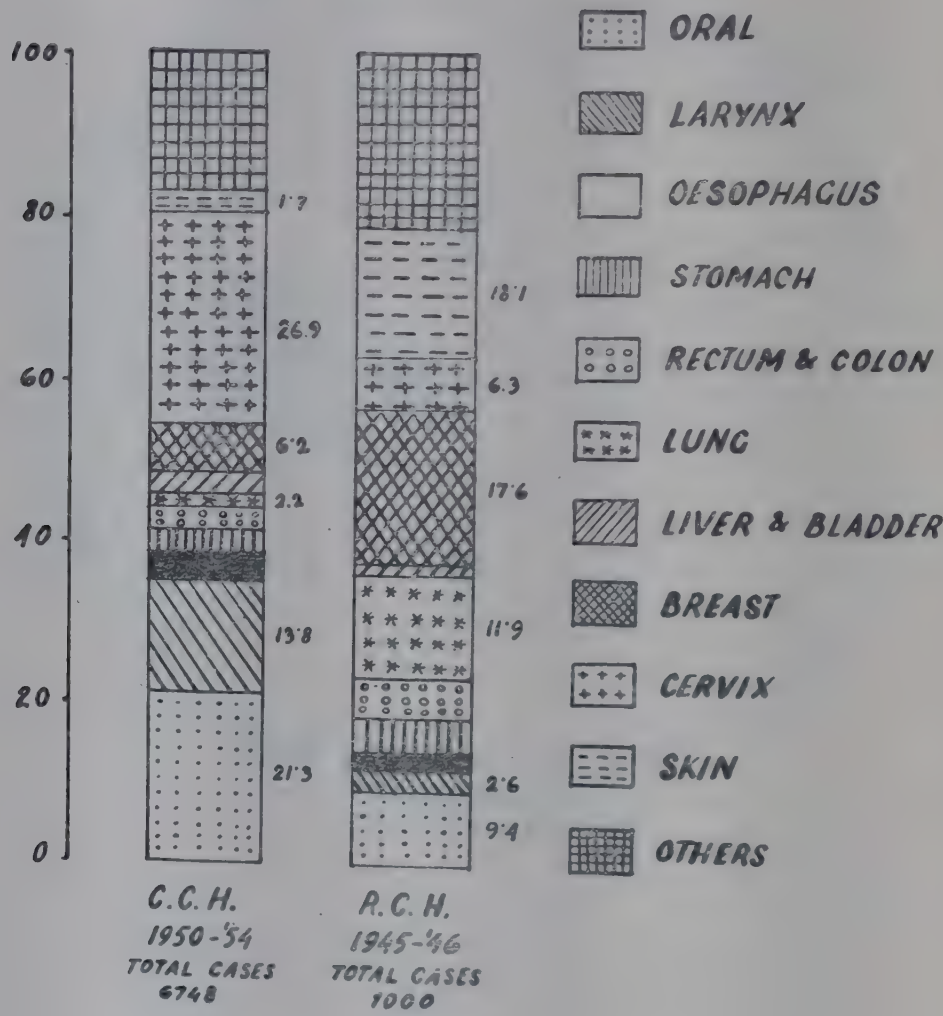


TABLE 1.

*Proportion of Cancer Deaths in 100 Deaths from all Causes in Each Age Range
(and Percentage Distribution of Total 100 Deaths)*
[Calcutta Corporation Area, 1954]

Sex	Age range of life (years)						
	0-19	20-29	30-39	40-49	50-59	60-above	All ages
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1. Male ...	0.2 (25.3)	0.8 (4.5)	2.0 (4.3)	5.2 (5.1)	6.2 (5.6)	5.5 (9.0)	2.4 (53.8)
2. Female ...	0.1 (24.5)	1.1 (4.6)	4.0 (3.0)	8.8 (2.6)	9.5 (3.1)	4.5 (8.4)	2.3 (46.2)
3. All persons ...	0.1 (49.8)	0.9 (9.0)	2.8 (7.3)	6.4 (7.7)	7.4 (8.7)	5.0 (17.4)	2.4 (100.0)

TABLE 2.

Probability of Death from Cancer in Different Age Ranges
[Calcutta Corporation Area 1954, and 1951 Census West Bengal Life Tables]

Present age (years)	Age range of life (years)							
	Sex	0-19	20-29	30-39	40-49	50-59	60-above	Total
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1. 0	male	.001	.001	.001	.005	.006	.010	.024
2. 0	female	.000	.001	.004	.009	.008	.007	.029
3. 20	male	—	.001	.003	.010	.012	.019	.035
4. 20	female	—	.001	.008	.017	.017	.014	.057
5. 30	male	—	—	.003	.011	.014	.022	.050
6. 30	female	—	—	.009	.019	.019	.016	.063
7. 40	male	—	—	—	.013	.017	.026	.056
8. 40	female	—	—	—	.025	.024	.021	.070
9. 50	male	—	—	—	—	.024	.035	.059
10. 50	female	—	—	—	—	.034	.029	.063
11. 60	male	—	—	—	—	—	.055	.055
12. 60	female	—	—	—	—	—	.045	.045

TABLE 3.
Morphology

Cell Constituents	Normal Cell	Malignant Cells	References
Cell Wall ...	—	Electronmicrograph of Novikoff Tumour Cells : Contiguous cell membranes separated by a distance approximately $400\text{\AA}^\circ$. At some sites, the membranes of adjacent cells sufficiently separated. Specially at corners.	Howatson et. al., 1955.
Cytoplasmic Volume.	More cytoplasmic volume in comparison with nuclear volume.	Less cytoplasmic volume.	Staff. Vincent Mem. Lab. Pub. Am. Cancer Soc. 1950.
Ergastoplasm	Abundant ergastoplasm, chiefly in the form of bundles of roughly parallel double lines, suggestive of tubular canaliculi.	Very few organized ergastoplasmic structure and no prominent bundles of parallel lines. Ergastoplasmic structure in the form of vesicles.	Howatson et. al., 1955.
Mitochondria	<i>Populations :</i> More numerous in normal liver cells. <i>Dimensions :</i> Diameter fixed at pH 7.3, 0.35 to 0.74μ. <i>Shape :</i> Elongated forms. <i>Fine Structures :</i> Limiting membrane double layered. Cristae mitochondriales not prominent structures.	Less numerous in Novikoff tumour cells. Diameter in Novikoff tumour ranged from $0.24-2.4$ to 1.2μ. Spherical or elliptical —No elongated forms observed. Same. Cristae mitochondriales very prominent and dense and in higher magnification, double structures.	
Golgi Material	(<i>Electron micros. study</i>) Cells of epididymes of mouse : (a) Horseshoe-shaped arrangement, of large vacuoles. (b) Lamellae arranged particularly along the inner and outer border of the vacuoles. (c) Granules of low electron scattering power of about $400\text{\AA}^\circ$ in diameter, distributed and intimately associated with the lamellae.	The vacuoles or vesicles not horseshoe-shaped, irregularly arranged.	

TABLE 3—Contd.

Cell Constituents	Normal Cell	Malignant Cell	References
Nuclear Volume	<i>Volume :</i> Less in comparison with cytoplasmic volume.	More in comparison with cytoplasmic volume.	Staff. Vincent Mem. Lab. Pub. Am. Cancer Soc. 1950.
Nuclear Chromatin	<i>Hyperchromasia :</i> Not marked. <i>Chromatin pattern :</i> Regular finely granular.	Marked. Irregular in shape, size and orientation.	
Nuclear Membrane	Nuclear membranes measuring from 300 to 400Å ^o in total thickness, double-layered, outer layer more tenous than the inner. Regular.	Same. Less regular, irregular projections and indentations being common. Some instances of nuclear membrane deeping deeply into substance of the nuclei to form fissures, the walls of which contiguous or tubular crypts, with narrow lamina.	Howatson et. al., 1955.
	Less permeable to nucleoprotein.	Increased permeability.	Catchpole et. al., 1950.
Nucleoli ...	Smaller. Two forms :— (a) as twisted cords of a dense material of closely packed particles ; (b) as granular masses showing no particular organization. Less nucleolar populations.	Much larger and more diffuse. Increased nucleolar populations.	Howatson et. al., 1955. Margaret et. al., 1955.
Chromosomes	Less chromosome abnormalities. <i>Number :</i> In normal human endometrial cells varies from 4 to 104 (Timonen), 30 to 59 (Manna). In non-neoplastic human cervix from 27 to 68.	Increased chromosome abnormalities. Wide range of variation in chromosome number in cancerous cells of human cervix. Each patient has a characteristic frequency distribution with a peak within a narrow range (Manna).	Lurdford 1930, 1936. Timonen, S. 1950. Manna, G. K., 1954, 1955, 1955.

TABLE 4.

Tissue Chemistry

Constituents	Mouse		Human		References
	Epidermis	Carcinomas	Epidermis	Carcinomas	
<i>Minerals^a:</i>					
Potassium ...	347	313	322	—	Cowdry 1949
Sodium ...	168	147	123	—	
Calcium ...	44	9	16	8.5	
Magnesium ...	19	18	18	—	
Zinc ...	5.2	1.7	2.4	1.7	
Copper ...	0.58	0.10	0.54	0.16	
Iron ...	6.4	2.2	—	—	
<i>Calcium binding^a:</i>					
Free Calcium ...	30.8	1.5	—	—	
Bound Calcium ...	49.4	3.7	—	—	
<i>Nucleic Acids^a:</i>					
Nucleoprotein phosphorus ...	124	139	—	—	
DNA ...	935	582	—	—	
<i>Lipids:</i>					
Total Lipid ^b ...	28.6	19.1	21.3	—	
Lipid Phosphorus ^b ...	0.16	0.31	0.12	—	
Cholesterol ^b ...	1.66	0.66	0.95	—	
Photographically reducible lipids ^c					
—(A) ...	25.0	0	64.0	0	
—(B) ...	0.0	3.1 to 20.3	0.0	44.0 to 98.0	
Water ^d ...	60.0	81.6	—	—	
<i>Vitamins:</i>					
Biotin ^e ...	0.079	0.030	—	—	
Choline ^e ...	990	1150	—	—	
Inositol ^e ...	210	212	—	—	
p-Aminobenzoic acid ^e ...	0.96	0.58	—	—	
B ₆ Complex ^e ...	0.98	0.76	—	—	
Ascorbic Acid ^f ...	0.193	0.184	—	—	
<i>Enzymes:</i>					
Cytochrome C ^g ...	52	34	—	—	
Cytochrome Oxidase ^f ...	9.9	7.5	—	—	
Succinic Dehydrogenase ^f ...	1.4	2.9	—	—	
Adenylpyrophosphatase ^f ...	8.4	25.2	—	—	
Arginase ^f ...	61.0	732.0	—	—	

^a Mg. per 100 gm. of fresh tissue.^b Gm. per 100 gm. of dry tissue.^c Microamperes per 100 mg. lipid; lipid in carcinoma qualitatively different from that of epidermis.^d Gm. per 100 gm. of fresh tissue.^e ug. per gm. of fresh tissue.^f Q-values; quantity of substrate used or decomposed per hour (expressed in microliters of gas) per mg. of wet weight of tissues.

TABLE 4—Contd.

Constituents	Mouse		Human		References
	Epidermis	Carcinomas	Epidermis	Carcinomas	
<i>Nitrogenous Constituents :</i>					
Urea ^g ...	77	22	33	—	
Ammonia ^g ...	24	8	24	—	
Lysine ^h ...	5.15	8.18	—	—	
Isoleucine ^h ...	2.65	3.83	—	—	
Leucine ^h ...	4.17	5.28	—	—	
Methionine ^h ...	0.91	1.20	—	—	
Valine ^h ...	2.84	3.86	—	—	
Phenylalanine ^h ...	1.46	1.89	—	—	
Threonine ^h ...	2.43	3.17	—	—	
Histidine ^h ...	3.33	3.40	—	—	
Glutamic Acid ^h ...	7.90	7.72	—	—	
Cystine ^h ...	1.50	1.42	—	—	
Arginine ^h ...	11.50	11.42	—	—	
Tryptophan ^h ...	0.98	1.60	—	—	

^g Mg. of N per 100 gm. of fresh tissue.
^h Amino acid N as per cent of total tissue N.
ⁱ Mg. of ascorbic acid per mg. of nucleoprotein phosphorus.

TABLE 5.
Cell-Chemistry

Constituents	Normal Cell	Malignant Cell	References
Cytoplasmic RNA,	Nucleic acid containing aggregates bigger.	Cytoplasm of hepatoma cells contain smaller nucleic acid containing aggregates.	Catchpole et. al. 1950.
Protein ...	Not like tumour condition.	The proteins of the tumours show a shift towards the increase of basic protein. Proteins are transferred from the body tissue of Walker-carcinoma rats to the growing tumour without prior complete hydrolysis to free amino-acids.	Caspersson et. al. 1942. Arthor et. al. 1954.
DNA ...	There is mean basic DNA content in normal tissues. There is a small variation of DNA value from cell to cell.	A deviation from the mean basic DNA content. In such cases the DNA content is either considerably higher (30%) than the basic value or showed as their lowest amount as the double value. Much wider fluctuation in their DNA content from cell to cell.	Leuchtenberger, C., Leuchtenberger, R., Arline M. Davis, 1954.
Nucleoli ...	Morphological appearances, RNA and Protein contents are dependent on the stromal situation.	Morphological appearances, RNA and Protein contents are independent of stromal situation.	Caspersson et. al. 1942.

TABLE 6.

Cowdry's Sketch of relative increase or decrease of different constituents of cancer cells

<i>Increase :</i> (50% or more)	Lipid phosphorus : dry wt. ratio, succinic dehydrogenase activity, adenylypyrophosphatase activity, arginase activity, lysine, tryptophane isoleucine.
<i>Increase :</i> (less than 50%)	Water content, choline, leucine, methionine, valine, phenylalanine, threonine.
No Change	Ascorbic acid : NP ratio, specific activity of P ³² in phospholipid fraction, inositol (wet wt. basis), histidine, glutamic acid, cystine, arginine.
<i>Decrease :</i> (less than 50%)	Potassium : NP ratio, Sodium : NP ratio, Magnesium : NP ratio, Cytochrome oxidase, DNA (wet wt. Basis), Cytochrome C(Paraminobenzoic acid (wet wt. Basis), Vitamin B ₆ Complex (wet wt. Basis).
<i>Decrease :</i> (50% or more)	Calcium : NP ratio, Iron : NP ratio, Copper : NP ratio, Zinc : NP ratio, non-protein nitrogen (wet wt. Basis), Urea (wet wt. Basis), Ammonia (wet wt. Basis), total free amino acids (wet wt. Basis); chromatography), Biotin (wet wt. Basis), Ca ⁴⁵ uptake and retention, free calcium. NP—Nucleoprotein Phosphorus.

TABLE 7.
Microradiography with U.V. microspectrophotometry

	Vaginal squamous cell carcinomas of mouse				References
	Normal vaginal squamous epithelia of mouse		Peripheral cell layer of cancer cord	Inner parts of the cancer cords	
	(E ₂₆₅)Corr. 1 m	(E ₂₆₅)Corr. 4 m	(E ₂₆₅)Corr. 1 m	(E ₂₆₅)Corr. 1 m	
Means of corrected mean extinction values at 265 mμ per unit dry weight.	0.209 ± 0.009	0.155 ± 0.007	0.301 ± 0.021	0.275 ± 0.025	Moberger, G. 1954.
Means of corrected mean extinction values at 280 mμ per unit dry weight.	(E ₂₈₀)Corr. 1 m	(E ₂₈₀)Corr. 4 m	(E ₂₈₀)Corr. 1 m	(E ₂₈₀)Corr. 1 m	
	0.147 ± 0.009	0.114 ± 0.008	0.236 ± 0.015	0.238 ± 0.019	

m = mean value of the total dry weight per unit area with its standard error.

E₂₆₅ = mean value of the measured E at 265 mμ with its standard error.

E₂₈₀ = mean value of the measured E at 280 mμ with its standard error.

E₃₁₅ = mean value of the measured E at 315 mμ with its standard error.

The dry weight (m) and the measured extinction (E) are measured in the same area.

$$(E_{265})\text{Corr. 1} = E_{265} - E_{315}; (E_{265})\text{Corr. 4} = E_{265} - E_{315} \left(\frac{315}{265} \right)^4.$$

$$(E_{280})\text{Corr. 1} = E_{280} - E_{315}; (E_{280})\text{Corr. 4} = E_{280} - E_{315} \left(\frac{315}{280} \right)^4.$$

TABLE 8.

Biology

Biology	Normal Cells	Malignant Cells	References
Diurnal Mitotic Rythm.	Present.	Not found in animal and in man. (1), (8).	(1) Blumenfeld 1942. (3) (4) (5) Bul-lough 1949, 1949, 1950. (7) Cooper et. al. 1938. (8) Dublin et. al. 1940. (9) Fischer 1925. (10) Friesner 1920. (13) Letwiller 1940.
Metaphase : Prophase ratio.	In normal proliferation endometrium : 1.2, 0.95, 0.73, 0.94, 1.4, (av. 0.84). Ratio more variable.	In carcinoma of human female genital tract : 1.9, 8.2, 3.7, 1.7, 8.1 (av. 4.7). Less variable.	Timonen et. al. 1950. Therman et. al. 1951. Fardon et. al. 1952.
Mitotic Time : (Tissue culture)	Rat fibroblast : 33 min. (21-50 min.). Less variable.	Rat sarcoma : 56 min. (24-97 min.). More variable.	Lambert 1913.

TABLE 9.

Biology

Biology	Normal Cells	Malignant Cells	References
	<i>In Strat. Sq. epith. cervix (human)</i>	<i>In epidermoid carcinoma cervix (human)</i>	Mitra and De, 1954.
Resting Phase	48.79 ± 0.54%	84.16 ± 0.32%	
Mitotic Phase	0.75 ± 0.05%	4.68 ± 0.10%	
Differentiating Phase	48.78 ± 0.54%	3.57 ± 0.14%	
Degenr. Phase	2.30 ± 0.15%	7.59 ± 0.25%	
Retention in Preparatory Phase	Nil	77.84%	

SECTION OF AGRICULTURAL SCIENCES

President :—DR. S. P. RAYCHAUDHURI, M.Sc. (Cal.), Ph.D. (Lond.),
D.Sc. (Cal. & Lond.), F.R.I.C., F.N.I.

PRESIDENTIAL ADDRESS

SURVEY AND CLASSIFICATION OF INDIAN SOILS

LADIES AND GENTLEMEN,

I consider it a great privilege to preside over the Section of the Agricultural Sciences of the Forty-third Session of the Indian Science Congress Association and am extremely thankful for having been given this honour. The present Agricultural Sciences and allied aspects have grown up into multifarious specialized branches and the full grasp of each one is, no doubt, the sphere of many specialists in the individual branches. Consequently I have chosen to speak today on the general activities related to Soil Science and Agricultural Chemistry with particular reference to Survey and Classification of Indian Soils, the line in which I have been actively engaged. I have tried to indicate in the following pages the recent trends and future lines of work relating to Indian Soils.

Productive Soils : The prime necessity of the present day Indian Agriculture is a well-planned, well-understood and well-carried out programme of soil management in order that the soil will continue to produce satisfactorily in accordance with its capabilities. For this purpose, the necessity of manuring and fertilization, crop rotations as well as appropriate tillage at the right time under the right conditions should receive their full share of attention. Holding the soil in place against washing and blowing and keeping the soil productive over years need also to be stressed.

The change-over from the spectre of food deficit to self-sufficiency achieved by the country during the past few years has been in no small measure due to the increased awareness of the cultivators about the spectacular effect of synthetic fertilizers on growth and yield of crops. This awakening speaks well of the adaptability of the Indian cultivators to accept scientific and technological innovations in methods for increased crop production.

Fertilizers and Fertilizer Trials : The primary deficiency of nitrogen in all Indian Soils demands the highest priority to be given to the production and use of nitrogenous fertilizers. While Ammonium sulphate has so far been the only important fertilizer of this type that has been used and found to respond well on most Indian soils, fertilizers like urea, Ammonium nitrate, Ammonium sulphate-nitrate have of late been receiving consideration. The performance of these new fertilizers is being tested in field experiments on government farms as well as on cultivators' fields at 40 different centres located in different soil type regions under an

Indo-U.S. Agreement Scheme. Results on paddy and wheat crops have definitely shown that the new nitrogen carrying fertilizers are generally as efficient as Ammonium sulphate on most Indian Soils. Extensive agronomic trials have also cleared some doubts about the use of phosphatic fertilizers and brought out the fact that while increased yields are obtained by the use of nitrogenous fertilizers alone, a supplementary dose of phosphate on many of the soils will produce a sufficient additional response so as to give economic return for the application of the phosphatic fertilizer. While Superphosphate continues to be the standard phosphatic fertilizer for most soils, there is enough evidence to show that citrate soluble phosphatic materials like Dicalcium phosphate could serve as equally efficient fertilizers and may even prove superior on acidic and heavy soils on which response of Superphosphate is apt to be reduced by fixation. Recent experiments on Dicalcium phosphate conducted at the Indian Agricultural Research Institute show that the response of paddy on neutral and alkaline calcareous soils is comparable to that with Superphosphate.

On some of the wheat growing areas of Uttar Pradesh, Panjab and Vindhya Pradesh response to phosphate has not been obtained which points to the need for examining specific requirements of soils by analysis or field experiments to provide a guide for judicious use of phosphatic fertilizers where necessary. The use of potassic fertilizers has given no response except in some experiments in Bihar in which additional yields of the order of 2.5 mds. of paddy per acre with 20 lbs. K_2O have been reported. In general, Indian soils would appear to be well provided with natural reserves of potash for the requirement of crops except for some like sugarcane, tobacco, jute, etc. which may need supplementary potash, but more work has to be done in this line.

Mineral Nutrition: The above and other manurial experiments at the State Agricultural Laboratories have indicated vast potentialities of increasing crop production by the use of plant food elements in the form of simple mineral salts. The cultivator in India has, therefore, to be educated by demonstrations and propaganda about the concept of the mineral nutrition of plants. In addition to the experiments mentioned above, experiments in cultivators' fields, known as Stewart experiments, sanctioned by the Indian Council of Agricultural Research, are also in progress in different states. Under the Second Five Year Plan, the Indian Council of Agricultural Research has initiated a model scheme on Simple Manurial Trials on Cultivators' fields extending over the entire country, from April, 1956. A project on complex model agronomical experiments at 34 centres selected on soil climatic basis has also been started.

It is necessary to recognise that extensive use of nitrogenous and phosphatic fertilizers for increased crop production naturally warrants a close watch to be kept on residual effects of fertilizers like acidity and depletion of other plant nutrients from the soil by crop removal. The productivity of the cultivated lands can be maintained at the optimum level to the extent that specific nutrient deficiencies are diagnosed in time and remedial measures taken to apply suitable fertilizer mixtures.

In addition to their effect on plant growth, storage properties of the new nitrogenous and phosphatic fertilizers imported under Indo-U.S. Agreement have been examined at 20 centres of different climatic regions. It has been established that alkathene bags will keep all fertilizers which absorb moisture from the atmosphere, like Urea, in excellent physical conditions under all climatic conditions.

Soil Testing: Soil Tests are tools to aid in determining the fertility status of soils and in diagnosing nutrient deficiencies of crops. In foreign

countries, like the United States and Holland, they are used extensively as integral parts of advisory services offered to farmers by a variety of government agencies, farm organisations, etc. At their minimum they almost always include recommendations on needs for nitrogen, phosphorus, potash and lime. At their widest, they may offer advice on many special problems, including need for trace-elements, water requirements, suitability of particular soils for specific crops, reclamation of saline and alkali soils etc. The necessity of establishing soil testing laboratories for advisory purposes was for long being felt and it is gratifying to mention that, a chain of 24 such laboratories is soon going to be set up in different regions of the country. A central soil testing laboratory has already been established at the Indian Agricultural Research Institute where preliminary investigations on development of rapid soil testing methods suitable to Indian soils are in progress. Amongst the several methods worked out so far, the Alkaline Permanganate method for available nitrogen, Olsen's or Bray's methods for available phosphate and Morgan's method for available potassium have given promising correlation with crop response.

Radio Tracers : Fundamental investigations on phosphorus in plants and soils by using radioactive phosphorus (P^{32}) as tracer are in progress at the Indian Agricultural Research Institute. These researches have revealed and will reveal the phosphorus nutrient status of Indian Soils, the best method of placement of phosphorus and its exchange reactions in the soil. The technique for measurement of surface soil phosphorus by isotopic exchange with P^{32} is also being worked out.

Clay Minerals : The clay is the most reactive portion of the soil and by virtue of its powers of adsorption and ionic exchange capacities it controls the chemical and physical properties of soils, besides holding all the important elements of plant nutrition. Kaolinitic clays are known to fix large amounts of soluble phosphate from added fertilizers, whilst montmorillonitic clays, under conditions of alternate wetting and drying, and illitic clays under continuously moist conditions, similarly fix large amounts of potassium and ammonia from the fertilizers. The free oxides also play an important part in phosphate fixation as does vermiculite in the case of K and NH_4 fixation. The physical and chemical properties of soils ultimately depend upon the nature and amount of clay mineral-present. The work on clay minerals is a very specialised type of work and it is being carried out at the Indian Agricultural Research Institute and some State Agricultural Laboratories and Universities. In future investigations, the mineralogical make-up of the sands and clay fractions should play a prominent part in the classification of Indian soils.

Micro-Nutrients : The essentiality of a group of six elements, viz., B, Co, Cu, Mn, Mo and Zn in the nutrition and metabolic activity of plants and animals, besides the usual ten elements, has recently been recognised. No systematic work on the distribution of these elements in Indian soils has been done and the nutritional requirements of these elements by different crops have not also been properly assessed. Under certain conditions of soil and climate the amounts of these elements absorbed by plants from soil are not enough to supply normal requirements. Alkaline, over-limed, calcareous, strongly acidic, highly leached, eroded, sandy and peaty soils are likely to be deficient in the above elements and such soil conditions are not uncommon in India. Widespread nature of deficiencies of these elements in our crops and soils has also been recognised. Work in this important aspect of nutritional science with reference to micro-nutrients is in progress at the Indian Agricultural Research Institute under a co-ordinated scheme of work on micro-elements financed by the Indian Coun-

cil of Agricultural Research. Spectro-chemical methods for the estimation of micro-elements are also being used in assessing the micro-nutrient status of Indian soils and plant materials.

Soil structure and Soil Conditioners : The capability of any soil for growth of plants and its response to management depends as much on its fertility as on its structure. The importance of soil structure in soil classification and in influencing soil productivity can scarcely be over-emphasised. Soils with aggregates of spheroidal shape have much more pore space between aggregates, have more rapid permeability and are more productive than soils of comparable fertility that are massive or even coarsely blocky or prismatic. Poor yielding quality of the black soil (*Regur*) of Central India has been traced to a loss in soil structure resulting from bad drainage and waterlogging. Recent development of certain soil conditioners has brought to light the factors associated with the aggregation of soil particles. *Regur* with high clay content has been found to produce bigger sized water stable aggregates under treatment of soil conditioners like *Krilium*, *Polyack* and *Aerotil*. Increase in the degree of aggregation of saline and alkaline *regur* was observed under the treatments of tamarind seed powder and *Krilium*.

Micro-Organisms : Microbial conditions of soils, besides increasing their fertility, help in improving the soil structure, a condition so important for plant growth. Thus soil microbes play a very important role in agriculture. Several types of soil organisms gather nitrogen from the atmosphere in one way or the other and have it in the soil. One group works independently in the soil and the other in symbiosis with host plants. In spite of the attention of numerous agricultural scientists of the country, the causes and extent of nitrogen recuperation in soils of different parts of the country remain still unknown. The possibility of improvement of pulse yields by cross-inoculation with vigorous organisms from wild legumes still remains. Much work still needs to be done on the completion of effective and ineffective strains of rhizobium of common cultivated legumes in our soils.

With the increased use of fertilizers in the country it is essential that knowledge be obtained regarding their effect on microbiological population of the soil. Maintenance of a healthy microbiological population in the soil is very necessary for continued fertility of our soils. It may be necessary for soil microbiologists to devote some time and work on gaining information on the above aspects so that deficient systems of fertilizer practices can be developed for different parts of our country.

Soil Temperature : Crops require light, heat, air and water for their growth along with a foothold in the soil and plant nutrients from it. Light and air are usually present in abundance over which man has but little control. Heat comes from the sun and the temperatures attained by the soil at different depths below its surface are of importance in agriculture. Experiments carried out at the Central Agricultural Meteorological Observatory show that it is possible to lower or raise the temperature of soil surface quite appreciably by covering with a layer of chalk powder or charcoal powder respectively. A thin cover of vegetation further lowers the soil temperature. Besides, a thin layer of chalk can bring about an appreciable reduction of evaporation from the soil.

The relation between water and a complex body like the soil is one of the most complicated problems in soil physics. The complications multiply in the field where conditions are daily changing and where the meteorological conditions over which no control is possible, influence the movement of soil moisture to a very great extent. Soils show great variations in their

power to hold moisture, the depth to which moisture may percolate and the degree to which desiccation can take place. All these factors should be properly understood for Indian Soils in order to have an efficient agriculture.

Survey and Classification of Indian Soils : After having discussed the general aspects of soil and its fertility I would now like to speak on the work done on the Survey and Classification of soils indicating some of the important lines of work in this direction.

Aims and Objects : The importance of soil and land use survey has been well recognised only within the last few decades and has been studied in a scientific manner. Soil surveys not only systematise facts regarding soils but also primarily serve as a basis for proper utilization of the results of past and present experiments regarding the response to manurial application, cultural practices and other agronomical operations in order that the information thus obtained may safely be applied to other soils having similar characteristics. The ultimate purpose of soil survey lies in the provision of accurate maps required for classification, interpretation and extension of data regarding agricultural production, the utilization of rural lands and to plan a sound programme for the development of rural area or even a small unit like individual farm.

The purpose of soil survey is admittedly utilitarian (for purposes such as revenue and taxation, settlement, agriculture, reclamation, irrigation, soil conservation, forestry, engineering, viz., road and building construction), but its importance to pedologists consists in an elucidation of the regional relationship of soils and the influence of climate, parent material and topography on soil genesis. The history of soil survey in India may be traced back to the early days when the system of soil classification for the purpose of land assessment for revenue was based on soil colour, texture and depth of soil crust. Maps showing the nature and extent of agricultural land together with topography, geology and forests are available for many parts of the country. There have been a good number of soil surveys of limited areas with specific objectives such as fertility surveys, pre-irrigation and post-irrigation surveys and genetic surveys. However, the basic knowledge of the soil types which form the physical basis for land use is incomplete.

Categories of soil classification : Soils in India have so far been classified from the following points of view :

(i) Soil classification from geological point of view where soils are grouped according to the geological character of the rocks which underlie the soil.

(ii) Land assessment classification where this system has been used mainly by Settlement Officers and is based on the suitability of soils for certain crops under local conditions.

(iii) Soil classification from the point of view of physiological properties where the classification is based mainly on the contents of nitrogen, phosphorus and potassium useful to plants, i.e., on the nutrient status, lime content and the mechanical composition of surface soil and subsoil.

(iv) Classification on profile basis where soils are grouped according to the morphological and physico-chemical properties of the soils. Such studies have been carried out mainly in connection with irrigation or afforestation projects and in some instances for agronomic purposes.

(v) Pedological classifications wherein the soils are grouped on the basis of their origin and development ; some work has been done in our country on this line.

(vi) Soil classification for land use.

Brief review of earlier work : A scientific approach to the study of Indian soils and their classification was first made by Leather (1898) who distinguished four major groups of soils, viz., : (1) the Indo-Gangetic alluvium, (2) the black cotton or 'regur' soils, (3) the red soils lying on metamorphic rocks and (4) the laterite soils. The relation between the broad soil zones of the country and the basic foundations have been discussed by Wadia, Krishnan and Mukherjee (1935). They have pointed out that the approximate boundaries of these soil groups are nearly coterminous with the boundaries of the geological outcrops. Raman and Satagopan (1935) characterized the climate of India by annual rainfall minus the annual evaporation. Champion (1936) presented a map showing distribution of fifteen climatic types. Not much work has, however, been done correlating climate or vegetation or both with the formation of the soil. Basu (1937) pointed out that the soils of India show certain differences in different zones divided on the basis of Lang's factor. Hosking (1937) employed Meyer's factor in his studies on the relationship between the Black earths of Australia and the black soils of India. Viswanath and Ukil (1944) prepared a soil map of India portraying the different climatic types on the basis of N.S. quotients. Based on comparative studies on 49 selected soil profiles of India, Viswanath and co-workers (1944) adopted colour and texture as units of classification and these in turn were treated on a background of four major climatic zones, viz., arid, semi-arid, humid and perhumid. A study of the soil profiles of the Panjab plains with reference to their natural flora has been made by Hoon and Mehta (1937). Raychaudhuri and Chakravorty (1943) studied the influence of annual rainfall and altitude above sea level on the silica-alumina ratio of the clay fractions of the red and lateritic soils.

Genetical soil studies and classification of soils based on morphology, physical, chemical and mineralogical compositions are of comparatively recent development in the country. Sen and Deb (1941) and Raychaudhuri and co-workers (1941, 42 and 44) studied the lateritic and red soils of India and divided them into five categories : (1) Laterites, (2) Lateritic soils, (3) Red earth, (4) Red loam, and (5) Red Sandy Soil, on the basis of variations in the physical, chemical and mineralogical composition down the profile. Mukherjee and Das (1940) in their studies of Kumaon Hill soils at Chaubatia in Uttar Pradesh found four major genitic types, e.g., forest soils, podsols, red loams and weissenboden. Basu and Sirur (1938) in their survey of the canal zones of Bombay-Deccan classified soils into twelve types as follows : (1) Oromorphic (high level shallow soils) with series and types G, H and F, (2) Phytomorphic (low level shallow soils) with series and types E, A, D, K and L and (3) Halomorphic (deep soils, low lying) with series and types C, I, B and J, normal saline phase. Tamhane (1950) concluded that Regurs belonged to the Tschernozem group and were closely related to Black Earths of Australia. Mukherjee *et. al.* (1951) distinguished three major soil types depending mostly on the degree of calcium leaching down the profile in their soil survey of the Gangetic alluvium of the Gorakhpur district of Uttar Pradesh. An integrated study of the effect of climate, vegetation and topography on the formation of the soil has been made by Raychaudhuri and Mathur (1954) who have divided India into sixteen major basic soil regions and 108 minor basic soil regions.

Broad Soil Groups : From the brief account of different soil studies given above, it is possible to recognize the following broad soil groups in

India although all these soil groups have not been studied with equal emphasis :

- (i) Red soils which may be classified as Red earth, Red Loam, Yellow Earths, etc.
- (ii) Laterite and Lateritic soils.
- (iii) Black soils of varying types, including the black cotton soil or 'regur'.
- (iv) Alluvial soils, (ill-defined).
- (v) Forest and Hill soils.
- (vi) Saline and alkaline soils.
- (vii) Desert soils.
- (viii) Peaty and Marshy soils.

Important fundamental studies on soils have been carried out by Mukherjee and his associates (1937, 1942 and 1945) who brought to light a number of features common to the colloidal constituents of soils of different origin and type. They also revealed characteristic variations between clays obtained from different soils and a system of differentiation of clays has been worked out based on such variations.

A large amount of data has accumulated as a result of extensive studies on soils in which tea is grown, under the auspices of the Indian Tea Association. A few soil maps of India have also been prepared under the auspices of the International Society of Soil Science (1932), the Geological Survey of India (1935) and the Indian Agricultural Research Institute (1943, 1954). The Indian Council of Agricultural Research Scheme of collecting and collating existing information on Indian soils was conducted for three years (1942-45). The final report of this scheme (1953) summarises the position regarding soil survey and soil study in India till 1945 and gives maps showing general distribution of soils in the States. These data are further being brought up-to-date under a new scheme financed by the Indian Council of Agricultural Research.

Fertility Surveys : The fertility surveys were carried out in areas covering Guntur, Krishna, West and East Godawari Districts in the Andhra State, and Tanjore, Malabar District and the Periyar tract in Madura District in the Madras State. Such surveys were also carried out in a few talukas in the Travancore and Cochin State. These surveys were in connection with the fertility status and manurial requirements of the soil in relation to the paddy crop.

Dr. A. B. Stewart of the Macaulay Soil Research Institute (1947) laid special emphasis on the importance of soil survey. He recommended fertility experiments District-wise on the basis of firmly established results on Government farms and the carrying out of the soil survey of all such experimental plots for final correlation between soil types and yield data. This recommendation was accepted by the Indian Council of Agricultural Research and was implemented in different states.

In Uttar Pradesh, the soil survey programme carried out at five soil survey zones by Agarwal (1953) includes those which are necessary to determine the important characteristics of soils ; to classify soils into defined types and other classification units ; to show on maps the distribution of different kinds of soils and to find the best fertilizer requirement of soils for soil improvement or increased crop production. Two types of soil surveys are being carried out, viz., (1) Reconnaissance survey, the widest application of which is in the determination of the responsiveness of soil types to management including fertilization, crop rotation, drainage, irrigation, reclamation, etc., and (2) Detailed survey, where soil variations are studied much more intensively in the field with the village as the unit of

survey. The soil survey map of the entire districts or detailed maps of the selected smaller areas in the districts are published from time to time and they contain all relevant information on the main soil types found in the various districts and serve as the inventory of the soil resources of that area.

In order to find out the best fertilizer requirement of soils for building up fertility, a large number of fertilizer trials on cultivators' fields have been conducted and crop response to major fertilizer ingredients like Nitrogen and Phosphorus has been assessed. In almost all the cases there has been additional production both through Nitrogen and Phosphorus.

Irrigation Surveys : In connection with irrigation projects, extensive soil studies have been done. These soil surveys aim at determining water relation of soils and classifying them into those suited and unsuited for irrigation. It has been felt that pre-irrigational soil survey is very important and equal emphasis has also been laid on post-irrigational soil survey and hence in many parts of the country under certain river valley projects such surveys have been carried out. An investigation in connection with the Tungabhadra project showed that two major groups of soil, red or reddish brown and black cotton soils were graded according to the depth of soil and the character of the subsoil layer so as to fall in line with the suitability of irrigation. Another soil survey was conducted in connection with the Gundlakamma irrigation project in Guntur District. The final conclusion of this survey was that irrigation may be safely introduced, if adequate drainage was provided. Pre- and Post-irrigational soil surveys have been carried out in the State of Mysore, viz., (1) Irwin Canal Soil Survey, (2) French Rock Soil Survey, (3) Shimsha Project Survey in Mandya District, and (4) Vanivilas Sagar Soil Survey in Chitaldurg District. The soils of the area covered by the Irwin Canal Survey vary in colour from red, yellow to brown. Grey soils are found near valley lines and water courses. The red and brown soils are open in texture, well drained, poor in organic matter, lime, total and available phosphoric acid and nitrogen.

The irrigation department in Bombay State surveyed the soil and subsoil of the Deccan Canal tracts and classified the soils in order of their suitability for irrigation on the basis of the morphological features, topography, depth of *murum* and substrata.

The survey of lands for irrigational purposes under a scheme of Lift Irrigation Projects was also carried out in the Bombay State. The problems here were different from those under canal irrigation described above as they pertained to smaller areas under limited irrigation which were to be mainly used for growing the food crops. In this case where an area of 35,000 acres was surveyed under 16 Lift Irrigation Projects, profile samples were taken up to a depth of 8 feet at traverses of 1320 feet and subjected to detailed chemical analysis bearing on the suitability of soils for irrigation. On the basis of the combined information, the areas were divided into six land-use classes showing the suitability of the lands for irrigation and crop growing. Map showing the distribution of the land classes for each area was prepared and supplied for use in planning of cropping programmes for each project.

The Panjab Irrigation Research Institute has been doing a number of pre-irrigation and post-irrigation soil surveys in different districts of the province in connection with land reclamation. Soil classification is based on (1) high alkalinity and high salt content throughout the profile, (2) high alkalinity and low salt content, (3) low alkalinity and high salt content, (4) high alkalinity only at the surface with the low salt

content throughout the profile and so on, taking into consideration pH and distribution of total soluble salts along the depth of profile. Soils with high pH and high salt content are recommended for reclamation. Usually the surface and subsoil samples are analysed for clay, silt, soluble salts and less often for exchangeable bases. The soil profiles up to 3 feet or more are generally examined but morphological characters are not always taken into consideration. The latter are particularly important in assessing factors such as rise of water-table and salts and waterlogging which are prevalent in the irrigated tracts.

Pre-irrigation soil surveys have also been carried out in the Hirakud Dam Project (Orissa), Kakrapara Weir Project (Bombay), Upper Mahanadi, Jonk, Bargi, Tawa and Punasa Dam Projects (Madhya Pradesh), Chambal Hydroelectric Project (Madhya Bharat), Rajasthan Canal Project (Rajasthan), Kosi Project (Bihar) and Gandak Project (Bihar). Soils classified on the basis of texture, depth of soil crust, pH and total soluble salts are mapped on suitable scales. It has also been brought out from the survey of these projects the trend of variation of the different soil features as indicative of the implications in the proposed agricultural development of land in these areas. A major part of the areas in those projects has potentially rich soil but is at present yielding mainly one crop and for its water requirements is entirely dependent on the rainfall. A provision of controlled supply of irrigation water would be a boon to increase the crop yield and to improve the economic condition of the areas.

The possibilities of reclamation of Rann of Kutch, an area of 15 hundred sq. miles, and its agricultural suitability were under investigation (Satyanarayana, 1951). The soils of the Rann area are heavy and contain sodium chloride and sulphate. An important point of great value for reclamation is the presence of large quantities of gypsum and calcium carbonate in the soils and availability of large quantities of flood waters, now running waste for desalinising the soils. A scheme for the reclamation of over 3 lakhs acres in the first instance is under consideration.

The Damodar Valley Corporation has surveyed large areas commanded by different reservoirs and classified the soils into different categories based on physical properties, (type of soil and depth) salt distribution and permeability (taking into account any pan formation). The Irrigation and Power Research Institute, Amritsar, is also carrying out pre-irrigation survey of the project area under Bhakra Dam in the Panjab.

Land-use Surveys: Land classification forms the starting point in land use surveys for planning purposes, land classification groups, land according to their native characteristics, present use, yield capacity and these classes are then assessed with reference to their suitability for different uses contemplated in the plan.

Investigations of soil and land use survey have been carried out for some time in a number of villages round about Delhi where studies on soil genesis and preparation of soil and land use maps are in progress. Many a time the land classes follow the soil types, hence on the basis of the yields obtained and the management systems in vogue, the land has been classified into (i) good land consisting of mostly loamy sand and sandy loam under good well and canal waters, (ii) fairly good land lying in the *barani* area where limiting factor is water, (iii) pasture land, the use of land restricted to grazing, (iv) consisting of sand dunes and sandy ridges good for perennial vegetation like grasses and trees, and (v) unculturable land which is under buildings, ponds, footpaths, etc.

In classifying land according to its capability, the following factors are involved: (i) Inherent potentialities and permanent limitations of the

land for agricultural use, (ii) complexity, intensity or number of practices needed to cope with hazards in using the land after it has been conditioned or fitted for use, and (iii) practicability and feasibility of practices and treatments for each specified use in each locality. The land capability classes, therefore, indicate the correct management practices within a restricted area or set of conditions. The classes are set up according to practical requirements. Once that is done, the natural qualities or properties of each body of land determine the class in which it falls, and also the practices needed to maintain it in that class.

Soil Conservation Survey: The first requirement for the successful development and application of any technical system of land classification is a clear understanding of the problems for which the classification is needed. Every land-use plan is essentially a measure of soil conservation. Soil conservation surveys including soil erosion and land utilization for soil and water conservation planning including recommendation for erosion control on uplands, ill managed forests and the gullied lands which contributed most to this erosion menace thereby helping these lands to produce most and deteriorate the least, have also been attended to in some of the States. This survey is an inventory of certain physical conditions which are of importance in the proper use of land. These are texture of surface soil; permeability of subsoil and substratum; effective depth; depth and nature of underlying geologic materials which affect the depth of soil or may interfere with conservation practices; depth of water-table; alkali and salts; fertility; slope and nature of terrain; overflow hazards; kind and intensity of erosion as well as the present use of land.

Since 1945, conservation surveys have been undertaken by the Soil Erosion Section of the Land Improvement Research Project of the Bombay State. Their object was to assess the damage caused to soils by erosion and classify the soils according to their suitability for different kinds of land use on the basis of the examination of the soil, slope, rainfall, vegetation, etc. The work has been carried out at various centres chosen at random in the scarcity tract of the Bombay Deccan. A complete catchment is taken as the unit for investigation. A survey of 50,000 acres carried out at twentyeight centres selected at random shows that only 17 to 23 per cent of the area is not affected by erosion while over 60 per cent is affected to such an extent that only 9 inches of the soil are left.

Soil conservation surveys for land development have been carried out in the Damodar Valley which give a picture of the magnitude of the problems of soil conservation and serve as a guide to make an estimate of the cost of soil conservation measures that will be needed in a catchment. Such soil conservation survey maps will provide the guide on the basis of which final land capability maps will be prepared, delineating land capability classes, suggesting detailed working plans for conservation and erosion, control on the uplands, denuded forests and gullied areas which contribute most to the erosion menace, by putting land to the use to which is best suited and recommending measures it needs to bring it into productive conditions. The area to be surveyed is divided into the various sub-catchments. The survey consists of two steps, the first is the cadastral survey to demarcate the present land-use like paddy, upland, pasture, forest, orchard, gullied land, etc.; the second consists of detailed soil profile examination and mapping of soil depth, soil texture, slope, stoniness, pH, permeability, degree of sheet erosion, frequency, depth and width of gullies, depth of gully heads and external drainage pattern. Soil profiles are excavated to the depth 4' to 6' necessary to identify the soil with certainty. On an average five soil profiles are studied in a square mile

area and the morphological features are recorded. The soil erosion classes are shown on the maps by a combination of numerical notation ascribed to each class. From erosion survey, the Damodar Valley Corporation has grouped soils into 6 classes according to suitability for land use and growing of crops: (i) paddy fields and upland, (ii) uplands with slopes up to 3% with moderate sheet erosion, (iii) uplands with slopes up to 5% with moderate sheet erosion, (iv) upland with slopes up to 3% with severe sheet erosion, (v) shallow lands, and (vi) lands of no use to agriculture. A working plan constituting some of the soil and water conservation measures depending on the nature of catchment has been prepared.

In the Bombay State, from the point of view of construction of bunds for checking erosion, survey is carried out to find out which are shallow soils, which are medium soils and which are deep black. The soils are defined as follows: (i) shallow soils, strata having soil depth less than 9 inches, (ii) medium soils between 9 and 18 inches, (iii) medium deep soils between 18 and 36 inches, (iv) deep heavy clay soils with soil depth over 4 feet and/or with clay content exceeding 30 per cent, and (v) alluvial deep soils with alluvial strata having clay content not exceeding 30 per cent.

There is an urgent need for evolving a procedure for a proper survey which would ensure a rapid progress of soil conservation work without involving much experimentation and research so that economy of time and effort could be achieved. In the light of the information available in India and other countries, a survey procedure which may be suitable for India is suggested below:

There will be three stages of operations. In the first stage the Basic Soil Regions (B.S.R.) of the whole country will be delineated. A Basic Soil Region is an area of more or less uniform conditions of soil, topography, climate and vegetation. Boundaries of such areas may be demarcated by superimposing the climatological, vegetation, physiographic and geological maps on each other and by utilizing other relevant information about those areas.

In the second stage the survey will be carried out in small areas selected at random and covering about 2 per cent of the total area of each B.S.R. Data for each selected area should be collected regarding present land-use, topography, slope, erosion, drainage, irrigation facilities, etc. In order to fix the slope classes within a B.S.R., an attempt should be made to develop suitable laboratory techniques to determine the slope classes.

The third stage is to carry out the soil conservation survey proper in order to get basic information required for the preparation of proper land-use plans for areas which are proposed to be undertaken for development. The cadastral maps of the areas may be used as base maps. Thus the soil, slope, erosion and inhibitory factors along with the B.S.R. delineations will make the survey maps of any given area more or less complete for soil conservation planning of that area.

Central Soil Conservation Board: The establishment of the Central Soil Conservation Board in India as per recommendations of the Planning Commission augurs well for the future of conservation in India. The main functions of the Board are to organise, co-ordinate and initiate research in Soil Conservation, to assist States and River Valley Projects in drawing up their soil conservation schemes, arranging for training of technical personnel and recommending financial assistance which would include both research, demonstration and extension. The Board has already established Soil Conservation Research Stations in Dehradun, Kotah, Jodhpur, Hyderabad, Bellary, Ootakmund, and Vasad. The establishment of this

chain of Research Stations located in typical areas of widespread erosion will serve to collect data on soils, land-use, rainfall and runoff under different conditions and effectiveness of various types of vegetation cover in arresting soil erosion.

It is, however, very necessary to conduct rapid reconnaissance survey of the major erosion affected areas by demarcating the type and the degree of erosion in each area together with the broad measures needed for tackling the erosion problem. Such a survey should be correlated with the Basic Soil Survey. Since this may take a long time, the utilitarian soil survey in such cases should be first taken up on a coordinated plan of work regarding technique of survey and classification.

Soil Survey based on Morphological studies on Soils: The best example of soil surveys based on morphological and other relevant examinations is that in the canal area of the Bombay Deccan. The soils of this area are tropical Black earths. Twelve types and phases have been distinguished depending mainly on whether the soils have developed under restricted drainage with varying accumulation of salts or under free drainage with varying contents of free lime in the profile. Other factors such as texture, moisture holding capacity, soil reaction, lime reserve and available phosphoric acid and potash have also been taken into consideration in arriving at the classification. On the basis of this survey, it has been possible to effect the following improvements in regard to sugarcane cultivation: (1) the adoption of recommendations in regard to the application of irrigation water and Ammonium sulphate, oil cakes, compost and Superphosphate has resulted in significant increases of cane yield for each of the five soil types and phases experimented upon, and (2) crop rotations suitable for each soil type have improved and maintained soil fertility. The adoption of the above recommendations has not only increased and maintained the productivity of the land but has also decreased by one-half the cost of production per ton of sugarcane.

In West Bengal, rapid reconnaissance (Schematic) soil survey has been carried out in the Districts of Murshidabad, Nadia and 24-Parganas. The soils of Murshidabad, on the basis of their origin and geographical situation, have been divided into two families, viz., Vindhyan alluvium and Ganga alluvium, which have further been subdivided into soil associations. The Ganga alluvium in the district Nadia consists of three soil associations, Ganga riverine lands, Ganga flat lands and Ganga low lands. These associations have been demarcated, based on natural boundaries and a tentative soil association map has been prepared.

A three thousand square mile area in the district of Burdwan and Hooghly has been divided into (i) laterites, (ii) red soils, and (iii) alluvium. Ganga and Vindhyan. A tentative soil association map has been prepared by examining soils in the field. Manurial trials with rice and jute have been conducted in each of these soil groups and associations.

In the Panjab, studies have been conducted on soils from typical areas of semi-arid and arid zones colonized by eleven types of natural flora and land devoid of any vegetation. It has been concluded that certain types of natural flora may serve as an index for judging the quality of land from the point of view of fertility and deterioration.

An area of about 37,000 square miles in the Panjab has been divided into the North Eastern mountainous region consisting of slopes and valleys and plains consisting of alluvial soil brought down by various rivers. The plains have been further subdivided on the basis of rainfall into submontane tracts, (35" rain), and the Eastern and Western plains

(10" to 25" rain). The hilly soils are acidic to neutral and the plains consist of alluvium, with copious accumulation of salts which develop alkalinity.

Khanna and co-workers (1954) have classified the alluvial tracts of Bihar, which constitute the "white sugar belt" of the State, into four broad divisions on the basis of variations in climate and nature of parent alluvium, *e.g.* (1) Non-calcareous, (2) Calcareous, (3) Heavy clay, and (4) Sone alluvium. These have been further subdivided into lower categories of classes, series, types and phases on the basis of the age of deposition, characteristics of subsoil materials, texture of the surface horizon and salinity or degree of base saturation of surface horizon respectively.

Butler in connection with his visit to India in 1951 to discuss soils visited the States of Mysore, Madras, Hyderabad, Bihar, West Bengal, Uttar Pradesh, Delhi, East Panjab and Bombay and examined some red soils, transitional soils between black and red, deep black and shallow black soils, laterites and alluvium, young and old met within those areas. The morphological features of those soils have been dealt with in detail in his report of visit overseas (1951).

Attempts have been made in the past to classify land on the basis of productivity index. Productivity is the capacity of a soil to produce crops in general or one specific kind of crop and it is the resultant of the qualities of the so-called natural factors of environment specially soil, climate and topography plus the human labour or management. Some soils need only to be ploughed and cultivated to produce good yields. Others may respond little to such simple operations, yet with more intensive practices like fertilization, liming, terracing, drainage or irrigation or some combination of these, high yields of good quality may be obtained. Proper soil management with the units of soil classification and soil maps should form the basis of any planning and land utilization.

Storie's productivity index comprises four factors A, B, C and X. Factor A relates to soil profile characteristics except texture, B relates to texture, C to land slope and X includes several factors which are known to modify the value of soil, with values of rating, ranging from 10 to 100 for drainage, erosion acidity, etc. Although Storie's index for productivity is a laudable attempt, but in some respects it is vague. In order to classify soils in the various River Valley Projects under investigation and construction, Hoon (1955) has tried to evolve alternative productivity rating formulae, and land has been classified into six basic classes on the analogy of the U.S. Bureau system of classification. The productivity rating limits have been worked out by applying two modified formulae for soils representing each of these classes of land ; whereas the productivity rating of soil is as high as 74 to 80 in the Panjab and near about that figure in soils of Bombay State (Broach Irrigation Project) that of Madhya Pradesh (Bargi and Tawa Projects) is between 65 and 70 and of Rajasthan about 16 to 28.

Thus it can be seen that soil studies with particular reference to survey have not been meagre but were not done under uniform and standardized methods adaptable to the country and in the system of classification there is a great lack of co-ordination and understanding on the genetic relationship of various soils so that the results of one farm cannot be applied to another with a degree of certainty.

Unlike the temperate countries, soil survey and soil classification in the tropical and subtropical countries have not made much progress due to natural disabilities. In recent times, however, increased attention is being paid to this problem. In a useful discussion that was held at the

First Commonwealth Conference on Tropical and Subtropical soils at Harpenden, England, in June, 1948, all soil experts opined that adoption of a common basis of classification of tropical soils was difficult in absence of detailed and authoritative information on morphological, physical, chemical and mineralogical properties of these soils. Referring to India, it was pointed out that the black cotton soil or 'regur' which, though superficially, has some resemblance to the Tschernozem, differs from it in many more fundamental aspects. Similar soils have been found in other tropical countries, such as Kenya, South Africa, in parts of South East Asia and Australia.

More stress is now being laid on soil survey in the country, and under the Indo-U.S. programme, soil survey is being carried out in 40 centres throughout India on soil climate basis. Majority of these centres fall under the Community Project areas or National Extension Blocks. These forty centres have been divided into six zones, with centres at Coimbatore, Poona, Nagpur Sabour, Kanpur and Delhi. The main object of this soil survey work is to study the soils of the above areas and find out representative profiles in the different regions and correlate them. The actual work was started in November, 1953. Up to July, 1955 work has been completed in twenty centres. Over and above this work, agronomic and socio-economic information have also been collected from almost all the villages surveyed so far.

The purpose of soil survey is not served with the completion of classification and mapping of the soils of a certain area. There still remains the important consideration of assembling the field data in a suitable cartographic form, and of writing a report which will convey a complete picture of the soils of the area, and their adaptability to crops within the particular climatic region. A Cartographic Laboratory has therefore, been established in the Indian Agricultural Research Institute to cater for the needs of the centralised agencies which have to provide facilities to field personnel in the preparation of base maps and final compiled maps.

Adequate soil classification in tropical and equatorial regions depends, first of all, on greatly increased soil research in these regions. Attempts to extend systems developed in the temperate regions into the tropics cannot be expected to be entirely successful. The more fundamental principles already learnt will be useful but classification depends so much upon the relevance of individual soil characteristics in combination, that only rough first approximations can be expected now. A great deal of field research is necessary to correlate combinations of soil characteristics, as determined by detailed morphological studies in the field and chemical, physical and mineralogical studies in the laboratory, with the geomorphological characteristics of the landscape and the responses of the soils to management.

The All-India Soil Survey on a soil region basis has therefore been planned for this purpose. Four regional centres are proposed to be established in alluvial, black, red and laterite soil tracts. These regional centres will be in charge of four soil correlators, one for each centre.

Organizations : The desirability of carrying out reconnaissance soil surveys on a co-ordinated basis had been emphasised in 1935 by the Board of Agriculture and Animal Husbandry, Government of India. Subsequently Sir John Russell in 1937 in his report to the Indian Council of Agricultural Research recommended the collection and examination of data on soil analysis made in different parts of India with a view to the preparation of soil maps. He also recommended the setting up of a small com-

mittee consisting of the leading soil experts in India to act as the correlating body. Following this recommendation, the Advisory Board of the Indian Council of Agricultural Research in 1939 emphasized the constitution of an All-India Soil Survey Committee. The object was to ensure that soil studies and soil surveys are carried out on a co-ordinated basis under proper guidance and that agreed and uniform methods of soil analysis are adopted and soil maps of India are prepared in consultation with soil workers. The Government of India, Ministry of Agriculture, established a Central Committee on Soil Science in 1949, of which Dr. J. N. Mukherjee was the Chairman. Later on, in view of the existence of the Soil Science Committee of the Indian Council of Agricultural Research, this Committee was abolished.

The Journal of the Indian Society of Soil Science is published by the Indian Society of Soil Science—an all India Body of Soil Scientists in India, with the object of cultivating and promoting Soil Science and allied branches of science and of disseminating the knowledge of soil science and its applications.

Training in Soil Survey : The Indian Agricultural Research Institute, New Delhi, provides two years' training in soil survey and agricultural chemistry for Associateship. The course includes a detailed study of soil survey and soil conservation. There is also a special short course of training in soil survey for six months for trainees deputed by different State Governments.

The Government of Bombay has also established a Soil Conservation Training Institute at Sholapur for training departmental personnel and other agricultural workers in land-use and soil conservation practices. Soil conservation is also taught as a part of the course of training students in Forestry at the Indian Forest Research Institute, Dehra Dun.

Since last year arrangement has been made under the Soil Conservation Board for special training for the State officers in land-use planning and soil conservation at Dehra Dun Soil Conservation Research Station.

Concluding remarks regarding classification and nomenclature of soils : The first need for soil surveys in India is classification and nomenclature according to carefully defined units of the lower categories. In the American system these would be called phases, types, series and families. Units need to be based upon both external and internal characteristics of soils as landscapes with special emphasis on detailed morphological studies using standard methods and terms for describing the individual characteristics. The significant horizons of representative soil profiles should be examined in the laboratory by these methods most likely to bring out the relevant characteristics of soils. The precise observations to make and the methods to use are not entirely known and considerable work is necessary before some methods can be standardized. Then, too, for basic study, detailed soil mapping is essential. A soil has boundaries as well as depths. One can see clearly its relationship to the parent rock, to the landscape, to management systems and to other soils only with the help of an accurate map. From the model profiles of the local soil types, by correlation, the model profiles for the higher categories—great soil groups—can be established satisfactory. In view of the lack of adequate data on Indian soils, especially morphological data, a real need exists for a first approximation to the higher categories of classification. Since several countries are directly concerned with well developed soils in tropical and equatorial regions, the great advantages of International co-operation and agreement on the broad groups and nomenclature of soils in the tropics and equatorial regions are obvious.

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SECTION OF PHYSIOLOGY

*President :—*DR. D. V. S. REDDY, M.B.B.S., M.Sc.

PRESIDENTIAL ADDRESS

"A PLAN FOR PHYSIOLOGY IN A SOCIALISTIC PATTERN OF SOCIETY"

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INTRODUCTION

I wish to express my deep appreciation of the honour my learned colleagues have done me in electing me the President of the Section of Physiology this year. I look upon my election as President, primarily as a gesture of goodwill and the friendship of the Physiologists of India. I am conscious of the inadequacy of my qualifications and achievements to fill this chair which has been occupied, with such distinction, by a galaxy of Physiologists. I can only claim that I am a devoted student of Physiology for over a quarter of a century. If I have accepted this honour and responsibility, it is only to get an opportunity to place before my colleagues and countrymen, some thoughts and ideas, gleaned during these years of apprenticeship and crusades in the cause of Physiology and to stimulate fresh efforts to secure for Physiology, in India, a place of honour, to which it is entitled by virtue of its inherent rights and potentialities for good, in the service of the nation. Our educated countrymen and women, some of our science graduates and science teachers, are blissfully ignorant of the elements of Physiology and the relation of this science, to the practice of scientific medicine, to the

preservation of health and to our comfort, happiness and efficiency, as well as its necessity to our normal life and thinking, to Society and Nation.

Presiding over the first Indian Science Congress, held in the rooms, of the Asiatic Society of Bengal in January 1914, Hon. Justice, Sir Asutosh Mukhopadhyaya, outlined the aims and objects of the Science Congress and stressed the need for personal contacts between Scientific workers in India, and added :—

“But personal association amongst scientific men may be pregnant with important consequences, not merely by a fruitful exchange of ideas ; cultivators of Science, by periodical meetings and discussions, may bring their aims and views prominently into public notice, and may also whenever necessary, press them upon the attention of the Government,—a contingency by no means remote, for, as experience has shown, even the most enlightened Governments occasionally require to be reminded of the full extent of the paramount claims of Science upon the Public Funds.”

Our Prime Minister, Sri Jawaharlal Nehru, in his extempore Presidential Address to this Congress in 1947 spoke on “Science in the Service of the Nation” and proclaimed “Scientists must think in terms of the 400 millions in India.”

GROWTH AND PRESENT STATUS OF PHYSIOLOGY IN WESTERN COUNTRIES

(i) *Changing Connotation and Expanding Scope :*

The word ‘Physiology’, derived from a Greek root with the Latin equivalent, ‘Physiologia’, and originally connoting ‘natural knowledge’ was first used in the mid-16th century by Fernel, as a substitute for ‘Naturalis pars medicine’, the first of the three parts of his treatise on medicine, including in its scope, the normal structure and function of the human body. Fernel’s book was immediately popular, and the term “Physiology” was commonly employed in subsequent teachings and writings. In the middle of 18th Century, with the publication of the monumental work of Albrecht Von Haller, “*Elementa Physiologiae Corporis Humani*” a purely biological connotation became widely or even generally accepted, and ‘Physiology’ included the study of structure and function of human body, together with a fair amount of comparative work. In John Hunter’s time, there was even a greater inclusion of comparative anatomy in Physiology. At the beginning of the 19th Century, particularly in France, studies of animal function began to include more and more of animal experiment. In 1809, Majendie, who was a practising physician all his life, made his scientific debut and brought Physiology in France back into experimental method, stated by Harvey in England. He was bold enough to say that he would like to place Physiology on the same sure footing as Physics and Chemistry. The new experimental method of approach resulted in separation of Physiology from gross and comparative structural studies, on which it had been based till then. In some centres, after the intimate cellular structure of the body had become known, the most exciting work of the Physiologist was in Histology. And the first Physiological Institute was that built for Purkinje in Breslau and opened in 1839. (Franklin)

In the second quarter of the 19th century, the greatest physiologist was in Germany. Johannes Muller inspired many brilliant youngmen to become physiologists among whom are many illustrious names.

During the second half of last century, Germany and France continued to be fountain heads in Physiology. Due to the developments in Physical and Natural Sciences, and the newer instrumental methods, Physiology struck out new and independent paths—put forth new off-shoots. Those men like Liebig etc., working in Chemistry founded the branch, Physiological Chemistry, later called Bio-chemistry, which has now asserted independence. Carl Ludwig, Helmholtz, Du Bois-Reymond gave a lead towards the Physical side—and laid the foundation of Physiological Physics, out of which sprang Bio-physics, fast becoming another independent branch.

Animal experiments and operative techniques were developed by Majendie, Claude Bernard and Pavlov.

It is only during the last one hundred years that the term 'Physiology' has acquired its present connotation and has been limited to the knowledge gained by scientific means, of the normal functioning of organisms or of their constituent parts. Claude Bernard, who is regarded as the father of Experimental Medicine, wrote in 1867 :

"Physiology which is the science of Laws of Life, incontestably deals with the most complex phenomena in nature. It is therefore, not astonishing that its advance should be so slow, and its appearance in the ranks of the exact sciences so long delayed." Later, he wrote, "Physiology, being the science of life, is to be regarded as an autonomous and independent study, to be cultivated for its own sake and not merely for its application for the practice of Medicine" (*La Science Experimentelle*. Paris 1878)

As Professor Sigerist (1943) points out, "Claude Bernard had not only made great discoveries, but had developed the experimental method into a tool that seemed apt to open the most secret recesses of nature. He endowed the whole generation of scientists with boundless courage and optimism. His influence reached far beyond the limits of science." His experiments at the College de France were attended by philosophers, historians and theologians, who were inspired by him to apply principles of experimental method in their studies and writings. "Physiology appeared to that whole generation as the Queen of all Sciences, because it was lifting the veil from the Mysteries of Life."

(ii) *Physiology in Medical and Veterinary Studies*

At the beginning of this century, the able clinician, Samuel Gee, told his new clinical clerk, Henry Dale, "When you enter my wards, your first duty is to forget all your physiology. Physiology is an experimental science . . . and a very good thing, no doubt, in its proper place. Medicine is not a science but an empirical art and it is as such, that you may learn something of it here. Some day, Medicine, too, might become an experimental Science." (Graham)

Today, the position is entirely different, and is summed up very graphically by Dubois (1950). Every year in an introductory lecture, I try to show the first year medical students, the place in their studies that is occupied by Physiology. I start off by drawing overlapping circles representing physics, chemistry and biology. On top of these and again overlapping, come the circles for anatomy, bio-chemistry and the other preclinical studies. Then comes a top overlapping layer of the clinical studies in medicine, surgery, etc. Finally, superimposed over most of the diagram, comes an oblong "Physiology" in red chalk, including parts of all the curriculum. Physiology has no limitations in any discipline that

deals with living matter. The more that Physiology invades anatomy, clinical medicine, and all the other departments, the better it becomes for science as a whole. It is not the title that makes the physiologist, it is the point of view, the mode of thought."

Leowi (1954) states "The marvellous development of human physiology in recent years is almost entirely due to the studies on organ level. To deepen our insight into the ultimate mechanisms underlying organ function, intensive studies on properties of cells become essential. *Medical Physiology* should expand the scope of its interest to the cellular physiology, which includes a great part of general physiology."

"Physiology, the science concerned with the study of the mechanism of life, must go deeper and deeper into the physical and chemical phenomena which in their integration make up the vital processes," say Guzman Barron, "Michaelis, with Loeb, pioneered in this science and introduced into biology the now well-known physico-chemical methods. As structural chemistry advanced and analytical methods for the detection and measurement of minute quantities were developed, physiology advanced in the study of the intricate mechanism of the interaction of molecular entities present in living systems."

(iii) *Physiology for the Culture and Discipline of the Mind*

Nearly one hundred years ago, Dr. W. B. Carpenter F.R.S. author of *Treatise on Animal Physiology* wrote :

"Study of Physiology serves a far more important purpose namely, culture and discipline of Mind itself." "It may be made to call forth a more varied and wholesome exercise of mental powers than almost any other subject. . . . It is only by the general diffusion of sound information on this subject that the public mind can be led to understand the difference between Rational Medicine and that Empiricism which now presents itself under so many different forms, that it can appreciate the true value of measures of sanitary reform, the efficiency of which must depend upon the amount of support they receive from an intelligent public opinion, and that it can be preserved from the epidemic delusions whose prevalence, from time to time, is not less injurious to the minds, of which they lay hold than in that of epidemic diseases to the bodies of those who suffer from them". I need not stress that these words deserve careful consideration by Educational and Health authorities in India today. Reviewing the treatise by Carpenter the Madras Quarterly Journal of Medicine wrote :

"We entertain very strong ideas of the importance of at least rudimentary knowledge of Physiology as an element of general Education". The review also mentioned that the University of Paris required from every candidate for its degree of Bachelor of Science, a competent knowledge both of animal and vegetable physiology and commended all interested in education in India the following remarks by the author upon the importance of this branch of study even to non-professional persons. "Every one who desires to see the study of physiology duly appreciated, as a branch of general education, must feel gratified at the progress which has been made of late years in the public recognition of its value. The University of London, led the way, by introduction of animal physiology into the programme of study to which all candidates to the degree of Bachelor of Arts are required to conform. The Universities of Oxford and Cambridge have since admitted it as one of the subjects which the candidates may select for their Bachelor of Arts

examination and in which they may obtain honours. And in many of the large public educational Institutions, with which this country is abundantly furnished, it forms part of the regular course of instruction". The reviewers praise those educationists in India, who "even with much difficulty and in face of determined opposition, succeeded in introducing this branch of study into our public schools in India".

Bayliss wrote in 1920, "Principles of General Physiology might be of service to all desiring a general elementary treatment of what may be called 'Abstract Physiology' as distinct from 'Applied Physiology' required by Medical, Veterinary, Agricultural students for the purpose of their profession".

(iv) *Physiology as an Independent Discipline*

Sir Frederic Hopkins commented "Medicine has been the foster parent of biological sciences and can therefore claim their loyalty—but Medicine has kept them too long in bondage—and not always realising their capacity for independent growth".

Sir Henry Dale (1932) points out that British Physiology developed as a "separate discipline of study and research, retaining an essential part in the training for Medical Practice, but acquiring a progressive independence in the choice of the ways of its approach to the central problem of the nature of vital phenomena". He says, "Of such cleavage from a parent science or discipline, physiology provides only one example among many. Botany and Chemistry first came to be studied in relation to the medicine of much earlier days and each long ago achieved a more complete independence than physiology has yet attained. Another analogy is presented by the relation of physics to science and practice of Engineering". "In any case the budding off of independent Sciences and specialization of scientific activities is a phenomena common to all sciences as a whole ; it is most active at the points of rapid growth, of which it is the inevitable consequence". Then, referring to criticism by some, of the "truancy" of Physiology from Medicine, an inevitable evolution, increasing the range of Physiological enquiry, independent of Medicine, Sir Henny answers, "If it implies that the daughter should resign her freedom and return to a perpetual and exclusive service of practical aims and needs of her parents, I think, we must firmly dissent from such a Victorian conception of filial duty, so harmful to the independent vigour of the parent, as well as to the free development of the new generation".

Stressing the value of relative independence of Physiology, he proceeds, "It seems to me beyond doubt, that this acquisition of a relative independence by Physiology and by other experimental offshoots from medicine and in the case of Bio-Chemistry from Physiology itself, enabling each to follow any new clue to new knowledge, without immediate and constant reference to a practical aim, has already achieved far more for medicine, than would have been effected under a permanent parental control".

PHYSIOLOGY IN INDIA—PAST AND PRESENT

(i) *Historical Background of Teaching of Physiology in Indian Medical Colleges :*

A critical and historical survey of the evolution of teaching and research in Physiology in India offers a partial explanation of the delayed birth, lack of nutrition and nurture of Physiology in India. In

the first place, we should grasp the difference pointed out by Puschmann between the continental medical schools staffed by Scholars and Scientists teaching devoted students of science and attached to Universities and the British Medical Schools which arose out of hospitals staffed by practising physicians, training apprentices for the profession. Secondly, during the opening years of 19th century on the continent, especially in France and Germany, Physiology was more advanced. In Paris and Berlin, there were established Chairs occupied by notable physiologists. In the first half of the 19th century, France was leading in Physiology, though very soon, Germany acquired a position of predominancy in Physiology. But in England, the ruler and preceptor of India, Physiology was to all intents and purposes, non-existent at that time, one hundred years ago. (Schafer)

When the Madras Medical School was started in 1835, the surgeon of the General Hospital supervised the teaching of Anatomy and the students were asked to copy certain portions from a book on Physiology. The scope and content of physiology was very limited (i.e. changes in the blood in lungs, liver and secretion of bile, digestion, and kidneys and urinary secretion). It was difficult for the native students to understand and follow the teaching in a foreign language. In 1847, when the duration and standard of instruction was increased, a new post of a Professor of Anatomy and Physiology was created. The school was officially raised to the status of a College in 1850, and offered three grades of instruction—with 5 years, 4 years and 3 years courses. Dr. Van Someran M.D. (Edin) Surgeon of Fort St. George Dispensary, was appointed Professor of Anatomy and Physiology. The text book used at that time for the higher grade students was "Manual of Physiology" by William B. Carpenter, M.D., F.R.S. Dr. William Nathan Chipperfield, M.R.C.S. (Lond.) though young in service, was appointed in 1859-60 the Professor of Anatomy and Physiology on account of his high attainments. The teaching of Anatomy and Physiology was bifurcated and entrusted to separate professors, one for Anatomy and one for Physiology. They had numerous professional, hospital, administrative duties and appointments along with the professorial work. The Superintendent of the Eye Infirmary and the Professor of Ophthalmic Surgery was given the additional duties of Professor of Physiology and Dr. Chipperfield thus became the first Professor of Physiology. But there was no laboratory and no practical class in Physiology. When Chipperfield went on leave or for war duties or took charge of another post, Dr. E. F. Brockman, Resident Assistant Surgeon and Professor of Materia Medica and Pathology used to act and later he was appointed to the chair of Physiology and Ophthalmic Surgery. It was during the seventies that microscopic studies of tissues were introduced and in the next two decades practical work in Physiology was limited to Histology classes. After Dr. Brockman's retirement, Dr. T. N. Pope, M.D., became Professor of Physiology in 1892. Dr. Pope was the last officer to hold the combined post of Superintendent of the Ophthalmic Hospital and Professor of Physiology. It was only in the early years of this century that the Professorship of Ophthalmology was separated from the Professorship of Physiology. Major Donovan, was appointed as Second Physician, General Hospital and Professor of Physiology, Madras Medical College, at the beginning of 1903. He was specially interested in microscopic work and discovered the Donovan bodies in the smears of the spleen and in peripheral blood. He introduced amphibian physiology, mammalian demonstrations and chemical physiology. After his retirement in 1918, Major G. E. Malcomson, Dr. M. L. Kamath and Major Skinner

successively held the post of Second Physician, General Hospital and Professor of Physiology. About 1925, a separate department of biochemistry was opened and the teaching of physiological chemistry was entrusted to this department. In July 1927, a full time chair of Physiology was created and Capt. B. T. Krishnan was appointed as the first full time Professor of Physiology, on a special cadre pay. It may therefore be stated that an independent department of physiology came into existence only less than 30 years ago. In India, we appear to be now in the same stage or age, in which England was about 1870-80.

(ii) *Facilities of Dissemination of Physiological Knowledge in Schools and Colleges*

A knowledge of Physiology, in the most comprehensive sense of the word, must be deemed as essential as the three Rs. Probably it is more vital for a healthy normal length of life than the three Rs, and necessary even for illiterates. Yet, there has been no attempt or even an idea to inculcate the elements of Physiology in the Basic Schools or primary schools or to teach Neo-literates. There are no teachers who can do this and there are no charts or books which can help teachers. At the lower secondary stage, some textbooks of elementary science in Regional Languages, include some lessons in Physiology. The words coined in the language used in the subject matter of these lessons, and the illustrations, are all defective and crude and distorted. Neither the student nor the teacher can understand the lesson or take interest in the subject. There are no charts or models, available in the schools and the teachers themselves have never been taught even elementary Physiology with the help of charts and models. In the higher secondary school stages, the students are supposed to continue the study of Human Physiology with the help of teachers and text books written by some high school teachers who have themselves never studied physiology, except in such text-books as existed in their libraries or in regional languages. Some of the bigger and richer schools may own some charts and models, locally made and disproportionate. At the University stage, only a small section, in a few well-equipped Colleges—students taking second group (Natural Science, Physics and Chemistry) are expected to study physiology and take a paper in Human Physiology. The lecturer who teaches Human Physiology is either a Botanist or a Zoologist and has never studied animal physiology or human physiology in his B.Sc., or M.Sc. Course. In former days, the Manual of Physiology by Huxley or by Foster and Shore, was followed. At present, the student depends on what may be called, "Made Easy series" or "notes" for examinations, written by Zoologists.

In undergraduate teaching, Physiology has a very limited place except in medical, nursing and veterinary education. In the Arts and Science Colleges, there is no provision to teach it for B.Sc. in many Universities. In Madras University, it was a subject for B.A., years ago but it is not so, now. Some attempts have been made to affiliate institutions affording facilities for B.Sc. Physiology but no progress has been made. It is now taught only as part of Home Science in a few Women's Colleges and as a Subsidiary subject, in the Madras Christian College.

In the Bombay University, as in London University, the students who have passed the First M.B. or taken the medical degree, are allowed to proceed to the B.Sc. Degree in Human Physiology, by taking an additional course. There is also a B.Sc. Course in Animal Physiology. But,

of late, there has been a dearth of candidates for this degree in Physiology, Anhdhra University copied, as early as 1930, the rules of the Bombay University and London University, but official and administrative obstacles have stood long in the way of Andhra Medical College being affiliated and sending candidates for the B.Sc. Degree in Physiology. I am gratified to learn that recently Andhra University approved of B.Sc. Physiology being instituted in Andhra Medical College.

The Calcutta University is the only one which has for a long time encouraged the study of Physiology in the Science Colleges. The Presidency College, Calcutta, has been a nursery of Physiologists, for India.

(iii) *Post Graduate Studies in Physiology*

Calcutta University was also the pioneer with regard to the post-graduate studies in Physiology for B.Sc. students, with well-equipped laboratories and competent staff, to train students for M.Sc. (Physiology) and for Ph.D. and D.Sc. Only those who have taken B.Sc., with Physiology as a subject, are allowed to take M.Sc. Ordinary Medical graduates are not permitted to take M.Sc. During the last few decades, other Universities felt the need for postgraduate degrees in Physiology for medical graduates. Madras University started M.Sc. Degree in Physiology and also in Bio-chemistry, by research. Lucknow University opened a degree M.D. in Physiology and Agra followed suit. The Andhra University copied the Madras University rules. Subsequently, in Madras, new regulations were framed making it compulsory for the candidates to submit a thesis and also sit for an examination, consisting of written, practical and oral. Bombay University has M.Sc. in Physiology but allows only those with B.Sc. Degree in Physiology. There is a separate M.Sc. in Bio-chemistry in Bombay, and Nagpur for Science graduates. The courses and syllabii, the type of training and type of examination and the number and standard of papers and type of examiners, vary from University to University. The long-expected up-graded department of Physiology for training of teachers and research workers, in a central place, has not yet materialised. It is hoped that with the guidance, supervision and control of post-graduate Medical Education by the Indian Medical Council, and the inauguration of the All India Medical Institute at Delhi, there will be a uniformity of standard and procedure for the Science and Medical Graduates qualifying for M.Sc. Degree in Physiology.

(iv) *Progress of Section of Physiology and Other activities in Physiological Domain*

As the number of Physiologists in Medical Colleges, in Science Departments of Universities and other Institutions in India increased, it was felt desirable to have a separate section for Physiology. After years of representation, it was only in 1936 that the section of Physiology was opened with much hesitation and apprehension. The President of the First Meeting was Dr. W. Burrige, a former pupil of Goetz at Oxford, and Professor of Physiology, Medical College, Lucknow, the only non-Indian who had occupied that position. The number of papers read before the section was 24.

The second meeting and the first anniversary in 1937 was in Hyderabad. Lt.-Col. S. L. Bhatia, an alumnus of Cambridge School and Professor of Physiology, Grant Medical College, Bombay, presided over the section. He referred to the inception of the section as a recognition

of the existence of Physiology and the workers in the field in India and by implication, that physiology is not to be regarded merely as a handmaiden of Medicine but as an independent science of fundamental importance.

Prof. N. M. Basu, who presided over the 4th meeting of the section, and gave his address on "PHYSIOLOGICAL RESEARCH IN INDIA", bewailed the neglect of Physiology in India, the low status and poverty of original work in Physiology. He said "Physiology has always been handmaiden of Medicine. Yet, it has been specialized independently of it, to a surprisingly great extent in the course of the last 25 years owing to incessant application of modern methods of Physics and Chemistry in the elucidation of its problems. If, therefore, Physiology is still kept in the leading strings of medical men, its growth would be hampered. This subject has developed to such an extent that it is given an independent position and is already a respectable science although it is not recognised to be so in this country due to ignorance of our educational authorities. It requires exclusive attention of its votaries."

Prof. Basu was not also happy about the teaching of the subject in Science Colleges. "Physiology is no doubt taught as an independent Science in certain Universities in B.Sc. and M.Sc., courses but these departments do not get adequate laboratory grant for equipment and research. The Physiology laboratories are so built that no provision was made for research and the Universities give no encouragement for any research in Physiology."

It was feared that the section, if started, would not continue on account of lack of research in Physiology in India. Going through the proceedings of the Congress from 1936, one notes the gradual increase in the number of centres and the Physiologists that send papers to the section, as well as the number, variety and quality of communications. The section is slowly but steadily gaining in strength and prestige from year to year, inspite of the unhelpful attitude and the obstructive tactics of those in authority, or power.

Let us look at the abstracts and analyse them. What are the types of subjects of investigations on which the papers are based? This graph changes from year to year with the special interest of the President or Recorder or some active or ambitious members. A large number of papers are received from one or two centres only—Calcutta or Izatnagar. Similarly, a good majority are from pure Physiologists, or from pure Veterinary Institutions. The largest number of papers are generally of a bio-chemical nature, including nutrition and metabolism. A few papers on Pharmacology, Histology etc., are also presented. The papers on Physiology do not form even 50 per cent, are on diverse topics and variable in quality. But, did we succeed in stimulating and promoting research, particularly in the Physiology departments of our Medical Colleges, now over 30 in number, equipped fairly well and staffed by men with long experience in India, or intense training in foreign universities, or with both advantages? One has only to look into the lists of members of the Science Congress and the printed abstracts of papers in Physiology, to realise, with a feeling of depression, that the Physiology Departments in our Medical Colleges have not begun to manifest any sign of Physiological activity.*

* After the address was delivered, I was told that I have omitted to make any reference to the progress of Physiological Research sponsored by the Ministry of Defence.

The Physiological Society of India was formed, to stimulate Research in Physiology, throughout India, and to focus the attention of Governments and Universities, for the expansion of Physiological studies and research and to help the growth of section of Physiology. The society passed through a childhood, suffering from infection and convulsions, malnutrition and hormonal deficiency, on account of lack of proper environment and financial assistance. But it is still alive and active. The number, however, of active workers in Physiology, the number of Physiologists in the Science Congress Association or in the Physiological Society or in I.C.M.R., C.S.I.R., National Institute of Sciences, is very small compared to the number of representatives, from other Sciences. India has not been able to send an official delegate to the International Congress of Physiology at Montreal in 1953. It is difficult to foresee when our country will be able to invite and hold in India the International Congress of Physiology. There is not one name of a Physiologist from India, who had acquired a high place by researches or contributions in any branch of Physiology. It is for the Science Congress to enquire into the causes of this pathological or morbid state of Physiology in India.

It is worthy of note that while many central and state laboratories have been conceived, planned and opened during the last 8 years for various branches of Medical Sciences and pure Sciences and Technology, there is not one Physiological Institute, sponsored by Central or State Governments or Private Endowments or Universities, for advanced Research and training of research workers in Physiology, with its numerous ramifications—General Physiology, Bio-Physics, Industrial Physiology, Environmental Physiology, Nutritional Physiology, Aviation Physiology, Neuro-Physiology, Muscle Physiology, Reproductive Physiology, Cytology, Cyto-Chemistry etc.

A PROGRAMME FOR PHYSIOLOGY IN THE SECOND FIVE YEAR PLAN

I. Importance of Physiology to Society and State

“The Second Five Year Plan is not a mere series of projects or programmes, but something much vaster—the mighty scene of a nation building itself—all of us working together to make a new India—not abstractly for a nation but for 360 million people.”

“National Extension service is seeking to create a new pattern of society to meet the new hopes and aspirations and the longing for a new order—to change the outlook of 27 million families living in the countryside, arouse enthusiasm in them for the new knowledge and new ways of life and fill them with the ambition and the will to live a better life.”

The Planning Commission has invited all of us, through the Universities to take our share in the making of the plans—The objectives of planning are full employment, increased production and social justice.

Gerard (1952) remarks “Today, most of our ways of life and some of our ways of thought, stem from Science and today the nature and future of Science are inseparably and irreversibly bound with those of the larger social group And social uses of Science have increasingly moved to front centre on the stage of Civilisation” “If Science is, as I have called it, the auto-catalyst of social evolution and if Science is an integral part of the social organism, it would be well to examine some of these changes. Nor is the task unrelated to Physiology, as such, for Biology is the study of Organism and Physiology could be called the Ecology of Cells in body, as Sociology could be called the Physiology of Society.”

"Science is inextricably bound to Government, to industry, to the people, in war and peace, for woe or weal. Science will evermore influence the shape of things to come. Scientists must recognise their social responsibility and must accept their social obligations."

A knowledge of physiology must be available for all like air, water and food. In ancient India, as well as in ancient Greece and Rome, the knowledge of the human body and its functions formed the discourses at gathering of people interested in general culture. Addison of Spectator fame wrote that he wished to bring philosophy from heaven into "clubs" in London. The science of physiology should similarly be released from Ivory Towers of Medical Colleges. It must be described in a simple manner to all literates and illiterates, according to their intelligence and interest.

The importance of physiology must be appreciated by the individual, by the family ; by the community and the state. The individual must understand something of his own heredity, environment, structure and function of human body, and the integrating mechanisms, regulations and adaptations, the body is capable of, and apply this knowledge to daily life and dealings with individuals, community and state.

The body has been very often compared to the body politic and the wisdom of the body has been the wonder, admiration and inspiration to all thinking men of all ages, who have not failed to suggest that all men, especially, those claiming to lead Nations should intensely study the organisation and working, integration and adaptation of the animal organism. Recently, there have been proposals for a school for politicians and ministers. May I humbly suggest that the principles of Physiology be given a place in the curriculum of that Institute, so that it may be useful as much for the preservation and promotion of health, as for the proper understanding the principles that control the functioning of the State.

Sir Walter Fletcher, Secretary of Medical Research Council, in a broadcast stated "We can find safety and progress only in proportion as we bring into our methods of state-craft, the guidance of biological truth."

II. Improved Facilities for Teaching of Physiology at Different Educational Levels

A. *As a pure science :*

1. Physiology in Basic Schools and fundamental education. 2. in High Schools. 3. in Arts and Science Colleges and in Degree Courses.

B. *Physiology as a social science :* for social workers, school teachers ; in Home Science Courses.

C. *As applied science :*

Physiology for nurses ; for Health Education, Health Inspectors, Physical Instructors, Pharmacy students, Dental students, Medical students, and for Veterinary students.

D. *Physiology in Post-graduate Courses :*

- | | |
|------------------------------|----------------------------|
| a. for M.D. & M.S. Students. | b. for M.Sc. (Physiology) |
| c. for M.Sc. (Bio-chemistry) | d. for M.Sc. (Bio-physics) |

There are now more than 30 universities in India. And yet, with the exception of Calcutta University, the Universities have not given any encouragement and taken steps for the promotion of teaching and research in physiology in their undergraduate or postgraduate curriculum. India attained her political independence but this country is still dependent on

foreign countries and centres of medical education and foreign Physiologists for the training of her younger teachers, and for import of apparatus and chemicals and literature, and textbooks, necessary for teaching and research in physiology in India. The physiology departments attached to the medical colleges in India are under the control of the Departmental Deities and Clerks, who cannot visualise the importance and expanding scope of physiology, even in Medical Curriculum. Unless physiology is taken into the fold of the universities and made to breathe and live in the atmosphere of academic freedom, drinking at the fountains of physical and biological sciences and drawing inspiration from the humanities and social sciences, Physiology will continue to be what it is now in India. The close association of University was the secret of the great achievements in Physiological Research in Europe and America.

It is not enough if Physiology is introduced as a subject for the B.Sc. degree. As Prof. Basu pointed out, candidates taking Physiology for B.Sc. must have a sound knowledge of basic sciences, Mathematics, Physics, and Chemistry. Those who do not take up Physics and Chemistry in B.Sc. should not be allowed to take up Physiology. Those who are going for Honours and M.Sc. in Physiology must have studied Chemistry and Physics in their B.Sc. course. The syllabus for Physiology in B.Sc. and M.Sc. should be more comprehensive and include all the branches like functional histology, bio-chemistry, bio-physics, animal physiology, general physiology and human physiology and recent advances in physiology. At the M.Sc. stage, students must be encouraged to take up research work and submit a thesis as part of the requirements for M.Sc. No student, who has not taken the B.Sc. in Physiology should be allowed to proceed to the Degree of M.Sc. by examination alone or by research and examination. Graduates in Medicine may be given special facilities and concessions to study and take B.Sc. in Physiology, after which they may be allowed to take M.Sc. There may be special provision for M.Sc. in Bio-chemistry or Bio-physics, or Animal or Clinical Physiology.

If proper selection of candidates for admission to B.Sc. is done, and if brilliant students are awarded scholarships to study physiology in B.Sc. there will be a good stream of physiologists flowing out of our Universities every year. Those who have shown aptitude for research and teaching or both, may be given research fellowships and enabled to proceed to M.Sc. and higher degrees and studies in India or abroad.

Others must be absorbed into educational institutions as secondary school teachers, into medical and health departments, industrial and social welfare services, into Pharmaceutical firms etc., and encouraged to study the various problems where their knowledge of Physiology is likely to be beneficial to the nation.

All the teachers of Physiology in the Universities must have at least M.Sc. degree in Physiology. And all the candidates applying for posts of Demonstrators in Medical Colleges must have taken their B.Sc., before or after their medical degree. No one who has not obtained a M.Sc. in Physiology should be taken on the teaching staff of Medical Colleges. It is not desirable to keep out an M.Sc. in Physiology, from a Physiology Department of Medical College, on the ground that he has no Medical Degree. It is more important to keep out a medical graduate if he has not taken an M.Sc. degree in Physiology. At the same time, there will be mutual advantage by adding to the staff of Physiology Department, medical graduates with post-graduate qualifications like M.D. and M.S., so that they get familiar with the methods, while the department in its

turn, will have the benefit of their clinical knowledge, training, outlook and problems, requiring investigation and elucidation. The department will therefore have a two way traffic and the contacts between the pure physiologist and the clinical physiologist is bound to be stimulating and fruitful.

III. Literature on Physiology required in India

(a) Text Books.

1. For neo-literates and adults.
2. For basic schools, and for fundamental or social education.
3. For secondary schools.
4. For general public.
5. For study in the Degree Courses.
6. Of an advanced type for post-graduates.

(b) Monographs on various branches of Physiology and on topics of special interest to India.

(c) Periodicals.

1. Journals for popular education.
2. For Universities and other educational institutions and libraries.
3. Journals devoted to reviews.
4. Journals publishing original papers, based on research.

(d) Audiovisual Aids :

The Union and State Governments must encourage and subsidize publications, charts, diagrams, filmstrips, models and films and electrical gadgets, illustrating physiological experiments, and make these available, free of cost, to all Community Projects and National Extension Service Blocks.

(e) There must be a section of Physiology in all Museums-State or Municipal, or College or School.

(f) Libraries : Public or University or College.

Must seek and stock the literature of physiology.

(g) Newspapers and Magazines :

Must also give some place to interesting articles and notes and models illustrating various branches of Physiology.

(h) Education through Radio :

A certain number of talks on physiological topics of general interest of educational value, or of sociological importance, should be included in the Radio programmes of various centres, in National and Regional languages.

SCIENTIFIC LITERATURE AND LIBRARIES

Sherrington, in his address, as President elect, of Association of Special Libraries (ASLIB) spoke of the estimated increase in the annual output of papers on Physiology to 1800 in 1927, and emphasised the magnitude of the problem. He referred to the importance of keeping in

touch with growing volume of contributions, from Italy, Japan, China and Latin America, and made an appeal for co-operation between institutions as the only economically practical means of securing a comprehensive and efficient service. We must have classified subject indexes to periodical literature, specialist Dictionaries, abstracts of foreign literature etc.

Dr. C. V. Raman has expressed the view, "The lack of real Indian Scientific Literature was the main cause of the backwardness of India, as far as Scientific Progress was concerned, and the cause of paucity of Scientific Literature in India was the absence of an organisation which generously supported the production of scientific books."

IV. Apparatus—Manufacture, Servicing Repair and Improvements

Collection of statistics of our needs and representation to National Physical Laboratory and Board of Scientific and Industrial Research.

The arrangements for loan and repair of instruments, grants for costs of instruments in the Physiology laboratories.

Central laboratories for manufacture of Physiological Apparatus—Regional laboratories for servicing and repair.

V. Animals Farms and Animal Breeding

"Arrangements of centres for breeding and supply of animals to Physiology laboratories. Supply of animal foods standardised and tested. Supply of literature on care and feeding of animals.

Research in building of animal rooms to suit the climatic conditions in India.

Training of Animal Houseattenders.

Facilities for large scale experiments and for experimental surgery on larger animals and primates. Experimental research on pedigree and cross breeding of animals to study the rate of growth longevity, resistance to disease and transmission of disease.

Domestication or development of new types of animal for experiments on Tropical Physiology.

*VI. Special problems and subjects in India**

TRAINING OF YOUTH FOR LEADERSHIP IN PHYSIOLOGY

I. Nurture of Physiological Talent

(a) Sir C. V. Raman, Nobel Laureate, in one of his Presidential Addresses to the Academy of Sciences observed.

"Our problem is not of constructing giant buildings importing expensive apparatus, and experts to erect them and still more experts to correct them, when the apparatus goes wrong.

"What India needs is men with devotion, capacity and self confidence to handle the activities in the fields of science—The Educational Institutions should aim primarily at bringing out talented students imbued with self-confidence and devotion and unconquerable human spirit and given these, there is no doubt of a great future for this country."

He urged the scientists in India to make use of the developments in other branches of Sciences, instead of solely depending on the develop-

* A brief and selected list of Physiological subjects and problems requiring urgent attention and investigation in India, in the second five year plan, was appended here but had to be omitted for want of space,

ment of their own particular fields. He emphasised the unity of the different branches of sciences and pleaded for the integration of scientific knowledge acquired in different fields.

(b) BRITISH SCIENTIST'S ADVICE FOR TRAINING OF BRILLIANT PHYSIOLOGISTS IN INDIA

As far back as 1937, Prof. A. V. Hill gave valuable advice to India :—

"Somehow, we must make Physiology intellectually respectable, so that men of really first class ability will be attracted to it. At Cambridge Physiology is as respectable as Physics. Claim for it an independent and honourable place such as Physics has. Do not let it be just a hand-maiden to Medicine. Physics is not the handmaiden for Engineering. Independence and an honourable position are required and if you can help to give Physiology in India these, you will get first class youngsters to join it."

Prof. Hill also gave counsel to attract brilliant young men and fit them for leadership in Physiology in India. "It is quality, not quantity or numbers which count in Physiology. One Pavlov produced more effect than 10,000,000 ordinary Russians in winning respect for his country." So guard and watch for and nurse the able youngster and make things easy for him and let him have as much independence as he can bear ; then send him out to see how things are done here or elsewhere. He will make friends ; he will win respect for his ability, he will aid in establishing in India also that International brotherhood which is superior to race, religion, politicians."

"A danger is that no man may be allowed to hold any place of importance in Physiology unless he has a medical degree. Avoid this tradition like poison. It means you will miss many of the ablest people of all :—Your Langleys, Barcrofts, Cannons, Baylisses, Howells, Bronks, Lucases, Kroghs, Lapicques."

Franklin wrote in 1950—"Physiology is not only an institute of Medicine but also a science in its own right. Many physiologists are neither medically qualified nor principally interested in the application of their findings to the understanding of diseased human beings. We should not discourage or dissociate from these others, for the history of all sciences contain many examples of what began as pure and ended often unexpectedly and sometimes very advantageously as "APPLIED".

(c) THE AMERICAN WAY

The American way of nurturing and training Physiological talent is described by Wiggers (1951). "Decisions to enter a given profession are not based entirely on inborn instincts. Somehow, somewhere, sometime, a seed of interest must be planted in the fertile soil. If properly nurtured and watered, it may sprout into a flower for the selected vocation, but it can grow into a study plant that blossoms and bears fruit, only through continued fertilization, spraying and pruning."

(1) *Evoking Interest of Promising Students in Physiology as a Career*

Wiggers relates earlier incidents and experiences that led to his adoption of Physiology as a career. His interest in Physiology as a Science was first awakened not by lectures or reading but through an educational experiment conceived by Lombard in 1902—i.e. assigning to each group of

two students a research problem to be carried out during the last two weeks of a laboratory course. His curiosity was aroused and he pursued the quest independently in the evenings and ultimately devised a simple method for studying the knee-jerk. About the same time, Cushny granted him the privilege of assisting in his experiments. The opportunity of watching investigators at work proved a great treat to a young individual.

Wiggers recommends that to evoke Research interest in students they should be exposed to experimental work and that the students' laboratory be so designed that it can be approached only through Research quarters.

(2) Give Opportunities to Youngmen to Realise or Detect Their Talents

Wiggers relates another more decisive incident. When he was thinking of eventually engaging in the practice of Obstetrics, the only Instructor in the Department of Physiology resigned and the authorities were unable to replace him. Wiggers was drafted as a half-time student-Assistant. He became engaged in a Research, which led to a demonstration, namely that Epinephrin constricts the cerebral vessels, and this, before the Annual Meeting of the American Physiological Society in 1905. He then realised or detected an aptitude for Research.

(3) Attending Meetings of Physiological Society

"Attendance at the meeting of the Physiological Society" adds Wiggers, "afforded a grand opportunity for gaining an initial acquaintance with many leading physiologists and for understanding how physiological advances are accomplished. Vivid recollections remain of the demonstration of the heart block by Erlanger, the registration of ventricular volume curves by Y. Henderson, the measurement of renal blood flow by Brodie, and the debate concerning the myogenic origin of the heart beat, which ensued after Carlson's paper on the Lumilus heart." Wiggers therefore urges that "Younger persons who seem to display an interest in physiological work should be encouraged to attend meetings of this sort and should be assured that the outlay of money required is well invested. . . . "In my case, it caused the seed of physiological interest to sprout and the resolution was made to enter physiology as a career, provided an opportunity arose."

(4) Selection to Teaching Posts

Wiggers continues, "The incidents surrounding my selection should perhaps be detailed for the benefit of younger physiologists, for they have implications even at the present time. I later learned from Lusk that Howell was impressed with the quality and manner of my presentations before the American physiological Society. I mention this so that youngsters may be reminded that it is still common practice to select and promote physiologists on the basis of their public performances at Scientific meetings."

(d) TEAM SPIRIT

Dr. J. C. Ghosh in his Presidential Address to this congress in 1939 regretted that team work was yet comparatively unknown in India and urged that for greater and higher achievements, we should all endeavour to inaugurate an era of co-operative endeavour.

Dr. F. C. Mann (1955) noticing the success of the method of group practice in States, conceived the idea of a group of scientists trained in Research in different fields working together on problems which require more specialized training than can usually be acquired by one individual. The selected scientists must also be capable of co-operation. All participants in each group could be equal and function on a voluntary basis. This scheme was a great success and deserves to be emulated by India.

If physiological research in India is to grow and blossom, as it did in Europe and America, it can happen only if there is a centre and a team of sincere workers in Physiological, Biophysical and Bio-chemical and Histological and Pharmacological fields, selected and appointed, not only on the strength of the qualifications or Research publications, but also after a psychological assessment, with a view to secure a co-operative team each complementary to the others, in talents, intelligence, equipment and qualities.

II. GUIDANCE IN METHODOLOGY AND PHILOSOPHY OF SCIENTIFIC INVESTIGATION

(a) Maurice Arthus (1943) in his 'Philosophy of Scientific Investigation', written as a preface to his monograph on "Anaphylaxis" postulates the responsibilities of a Professor ; "Besides, in publishing this book, I am fulfilling one of the basic duties that are assumed as a Professor. Indeed, the University Professor of Physiology must not only teach ; he must not only engage in original research intended to advanced science ; he must also endeavour to provide the young people who are emerging into scientific life, the physiologists, biologists and physicians—Our students to-day, our successors of tomorrow—with clear and precise directions, that will enable them to avoid the hesitations, the gropings, the disappointments, the errors, the discouragement, all those miseries of the beginning of the scientific career." He then proceeds to provide the young men entering a scientific career with the following directions and guidance : "Observe facts, conceive a hypothesis, determine its value through one or several series of judiciously instituted experiments, give the interpretations or more accurately, one interpretation of the facts and ascertain the excellence of this interpretation through strict criticism ; generalize the results experimentally without forgetting that an investigation must be pushed to the end."

In another place, he remarks ; "Seek facts and classify them and you will be workmen of science : conceive or accept theories and you will be their politicians."

"It is not enough to follow a good working method" says Arthus— "In addition, one must possess certain moral qualities. Chance in biology at least does not grant its favours to all and sundry. It seems to require from its proteges one quality—scientific curiosity. He who possesses that mental attitude is not content with looking casually at the facts that turn up. He examines the facts with sustained attention—repeats his examination as often as is needed, to distinguish between constant peculiarity and the variable elements. He describes, analyses, measures, controls, interprets, and in order to justify his interpretation, conceives an experiment that will demonstrate its worth or its emptiness."

"Among all the qualities that the experimentalist must possess, there is no doubt that none has greater value to him than tenacity. The experimentalist must ponder and meditate deeply over the problems raised, over the results obtained, over the experimental possibilities. Indeed, it is not

in the turmoil of social life, not through academic chats nor laboratory gossip that we come to see the light, that interpretations become clear, that experiments are conceived and conclusions reached. It is through solitary, profound and sustained meditation. In order to make some progress in the experimental sciences, one must meditate a great deal." Other special mental attitudes which are to be cultivated are the critical sense, precision in methods, and results, self-control and lastly intellectual independence and originality. "Preserve your originality. It is the result of the gracious and beneficial influence that your parents, your friends and the people of your home town have exerted on you. In respect and gratitude to them, preserve your originality; you owe it to them. Preserve your originality. It is this that will give your scientific work, its frankness, its grace, its elegance, its warmth and life among so many artificial, banal, common place, cold and corpse-like works."

(b) STARTING POINT OF INVESTIGATION—GADGETS, FACTS, *Versus*,
SPECULATION AND IMAGINATIVE THINKING

"The general tendency of our time to worship methods and gadgets" says Loewi, "has quite frequently placed emphasis on technical procedures and diverted interest away from physiological problems. It goes without saying that new methods elaborated in order to approach a definite problem, often have lead to the solution of many other problems. This has gone so far that sometimes one has the impression that in contrast with former times when one searched for methods in order to solve a problem, frequently now-a-days, workers look for problems with which they can exploit some special technique."

Loewi points out the necessity for speculation and imaginative thinking. "Working hypothesis should not be mistaken for preconceived ideas." Loewi quotes two passages. One is from a letter of Miescher, written in 1876 "In order to begin exploration of uncharted scientific field in which there is a lack even of the bare elements for posing clear cut questions, a unique type of imaginative power seems necessary. This can be designated as the building of mental bridges. It consists of visualization of main elements of the design based solely upon a few dimly indicated building stones. Out of these elements, the imaginative scientists make the first draft of the building plan. . . . It is in my opinion a malady of the present physiology that the method of preliminary synthetic thinking is coming into disrepute and that its application by the rising generation is intentionally suppressed." The second quotation is from Baldwin's "Preface to Dynamic aspects of Bio-chemistry." "Speculation plays and has always played an important part in the advancement of scientific knowledge; for, no research worker gropes blindly after he knows not what; he invariably begins with certain reasonable possibilities in mind. In short, he speculates."

Even contemporary Physiologists like Prof. Landis of Harvard says, "In physiology, particularly specialization and emphasis and technology must be balanced by recognizing the value of some philosophy within the science." Loewi believes that philosophy in this connection signifies an attitude towards the meaning and aim of physiology. "It is doubtless lack of such a physiologists philosophy that often leads to the over emphasis of isolated facts as opposed to ideas as well as of quantity as against quality. Facts are likely to be meaningless if they result from research which starts, not from a basic concept but from such reasoning as "nobody else seems to have done it so far, or what else can I do with my method?"

Loewi concludes, "For research, that can lead to the clarification of a problem or afford deeper insight into phenomena, imaginatory minds are indispensable"—"They may remain latent unless they get a chance to become manifest by seeing or performing experiments. For the development of an imaginative mind and the eventual realization of potentialities, favourable conditions must be established. In my view, the most important of these conditions is an inspiring apprenticeship which gets the student early into independent research."

(c) THE PHYSIOLOGICAL SCHOLAR

The Physiological scholar, "has the habit of seeing an alternative, of not taking the usual for granted, of making conventionalities fluid again, of imagining the foreign states of mind." Adolph (1954) pictures the physiological scholar "in the image of J. S. Haldane contemplating a generalization or L. J. Henderson hatching a hypothesis or R. S. Lillie dissecting a notion." All these physiologists who Adolph saw in action "loved pleasures of the mind and communicated their enjoyment." Adolph continues "As long as physiology is more than manipulation, physiologists are and will continue to be scholars."

(d) HISTORY OF SCIENCE—ESSENTIAL FOR UNDERSTANDING THE SUBJECT

Cauradias (1949) observes, "we can read ourselves into ignorance and stupidity if we do not seize the directive lines of scientific thought as shown through history. We have to think of our problems more and more closely with the help of the great intellects that have thought about them in the past. Scientific thinking—the basis of science can only be historical thinking."

A similar meaning is conveyed by a quotation on the title page of "A Short History of Physiology"—"He who wants to fully command a science must also know its evolution, its 'embryology'."

III. INSPIRATION OF GREAT CLASSICS AND ORIGINAL PAPERS WITH PERSONAL TOUCH

"Such passages—especially those which describe an important discovery have a peculiar fascination for many people, and they often prove a great stimulus to those who are entering upon the study of science." writes Fulton. "In many places where Physiology is taught, contact with the original sources is necessarily infrequent, and a pupil's outlook tends to be confined to secondhand knowledge obtained from lectures and textbooks. For many reasons, it is desirable that a medical student be conducted early in his career to the front line trenches of medical and physiological discovery. Let him realize that men as young as himself have made important contributions ; that de Graaf at 23 years of age devised the first pancreatic fistula ; that Helmholtz at 24 measured for the first time the heat production of frog muscle ; that Johannes Muller at 25 had enunciated the principle of specific nerve energies. Let him discover that simple facts were once hidden in a fog of faulty observation and faulty reasoning, and that it was sometimes the enquiring minds of students like himself that made matters clear."

Loewi considers that papers with a personal touch and revelations of author's scientific personality describing exactly the scientist's experience help much to inspire and educate the student of physiology. In his own

case, the reading of Gaskell's paper on "The rhythm of the heart and the nature of the action of the vague nerve" directed his interests towards the basic science. He expressed high regard for inspiring and educational value of papers like the one by Minkowski on "*Diabetes Mellitus, after extirpation of the pancreas.*" Loewi valued these papers for the particular lines of thought by which the discoveries came out. These thoughts could be grasped only by reading originals. Loewi used to request every student to read them before he began to work on a special problem.

INFLUENCE AND INSPIRATION OF GREAT MEN OF SCIENCE

Loewi next refers to the fact that the influence of great figures in science (who at the same time were great teachers) has been far greater than the influence of the printed matter. "Such persons were able to attract highly gifted students who in their turn augmented their heritage and frequently became leaders in Science in their own right." Loewi proceeds to illustrate this statement with examples recalling the most eminent students of three great figures who taught in the golden era of physiology in the 19th century.

"Johannes Muller, Carl Ludwig and Sir Michael Foster, according to all biographical data, shared to the highest degree the qualities of contagious enthusiasm, broadmindedness and imagination, humility and deep devotion to their pupils. These are qualities which in themselves suffice to attract outstanding students. I refer, however, to these figures because they attracted and educated students who later devoted their lives not just to physiology, but to other branches of science. This was made possible only because, through the mode of their education in physiology, the students were made familiar with principles which, transcending the boundaries of the special field, applied to many other realms of experimental science. Besides the art of experimenting and observing, they learned the ways of thinking, required by science. They learned how to select the object to be explored, how to interpret and evaluate the results obtained, and how to integrate them into the whole body of knowledge. In this way, students were not only made familiar with methods and facts, but were imbued with that general scientific spirit which shapes the pattern of the true scholar and investigator. They received the kind of education which in a seemingly paradoxical fashion is defined in that profound sentence: "Education is what remains when you have forgotten all the facts you ever learned."

"This kind of education can be acquired only if students have the opportunity to come into close association with their masters. The great masters amply provided this and thereby fulfilled a fundamental condition for the establishment of 'Schools' or trends of thought."

Need I remind this section and the Science Congress that such famous centres and renowned Preceptors of Medical theory, Clinical Physiology, and Clinical observation, flourished in Ancient India, and drew devoted disciples from West and East, i.e. from Greece and Middle East and from China and South East Asia. If the lost position and glory is to be regained, it can be achieved only by united and dedicated efforts and sacrifices of the Patriots and Scientists.

SECTION OF PSYCHOLOGY AND EDUCATIONAL SCIENCES

*President :—*L. J. BHATT, M.A., B.T. (Bom.), M.A. (Leeds)

PRESIDENTIAL ADDRESS

PSYCHOLOGY AS A PROFESSION

It is my foremost duty to offer you my sincerest gratitude for the honour you have conferred on me by electing me to preside over the deliberations of the Section of Psychology and Educational Sciences of the Indian Science Congress Association. I propose to use this opportunity to offer some observations on the problem of psychology as a profession and the closely related problems of teaching and research in the subject.

Psychology, which has many roots in the past and many specialised branches, is concerned with the systematic study of human behaviour and experience, including the complex influences which determine and control behaviour and experience. Psychology as a science has developed so rapidly that it is clearly legitimate to claim that there is no human problem or topic which does not come within the scope of psychology. Recent trends in psychology show that there have developed wide divergences of outlook and theory, an extraordinary development of a variety of techniques and a vast accumulation of findings from the laboratory and the factory, the social field, the clinical and the operating theatre. Still, however, the actual range of modern psychology is more limited than its potential range. Many of the current points of view are transitional and by no means final. They frequently represent the best construction or 'explanation' of the facts (or even facts themselves) which current knowledge and accumulated wisdom of the past can offer. Yet, much of our knowledge of human behaviour and experience is undergoing almost continuous change and development. Sometimes this is a very slow change, but viewed in a long historical perspective such changes, and sometimes even recurrent fashions in human knowledge, are detectable.

Psychology as a science has a fairly good standing in our country. Many distinguished men have occupied and are occupying important positions in the university departments with some solid achievements to their credit; some of our men have to their credit acknowledged work of merit which has brought for us self-respect as a profession. But my purpose here is not to give a description of the present position of psychology in this country; this has to be left out to satisfy demands for brevity. However, it is necessary to be aware of the fact that a new generation is taking over at some of the departments of psychology, and while once upon a time our objectives were purely theoretical and research work was not extended to include applied psychology, to-day most of our friends prefer to maintain an appreciable interest in theoretical as well as practical aspects of our subject. This new generation is not hindered by legacies of the

past and pre-conceptions left by traditions, and is helped by a fund of good will from the other sciences—a fund which should be cherished as an important source of strength. We will agree that Psychology as a science has, indeed, matured rapidly in the past ten years. Its affiliations with Education, Sociology, Biology, Industry and Medicine are now on a much firmer foundation, a foundation of mutual benefits. No longer afraid of the domination of philosophy, it can afford at least to acknowledge a debt to, and a need of, philosophy. And there should be now a wide range of professional openings for those possessing requisite psychological qualifications.

II

Occupations in Psychology : Last year some of our members joined hands to bring out a mimeographed *Directory of Indian Psychologists*¹ which was, in spite of difficulties, carefully compiled by a past president of this Section. We are able to see from this Directory that a large number of psychologists are engaged in teaching, research and administration in colleges and universities. Other psychologists are employed by hospitals, clinics and vocational guidance bureaus to administer tests, help make diagnoses, contribute to research, counsel boys and girls in the choice of subjects for their study. Psychologists are also found in the defence services, in industries and other services to help the organisations in selection, recruitment and training.

Still however, the opportunities for those who specialise in psychology or wish to take psychology as a vocation are limited. There is no doubt about the fact that psychology can be studied for personal, social and intellectual values. However, there still remains an urgent need to relate this study with occupational opportunities. It is certain that psychology is growing rapidly all over the world as a profession in recent years and just as physical sciences have made great contributions for our comfort and well-being, in the same way we can reasonably expect psychology to make comparable or even greater contributions to progress. If this is our hope, it will be quite useful to examine the most propitious fields to develop psychology as a profession in the context of careers and the preparation needed for them.

C. L. Shartle's study of "Occupations in Psychology" in the U.S.A. gives job descriptions of twenty-eight specialities in which the psychologists are engaged in that country² ; there are also other bibliographies on careers in psychology which are very suggestive. We can gradually develop all these specialities in the near future but we shall restrict ourselves here to a discussion of those fields in which we can reasonably expect the maximum expansion.

(a) *School Psychology* : School psychology will naturally occupy a position of eminence in the employment market in the near future, since a considerable amount of re-thinking about, and re-shaping of, educational system is taking place in our country. With the greater systematisation of Master of Education courses in the universities, the development will continue to be rapid though stable forms will take some more time to be

¹ Dr. Raj Narain : *Directory of Indian Psychologists*.

² Shartle C. L., "Occupations in Psychology".

established. The XIth International Conference on Public Education convened by UNESCO and I.B.E. says that the aims of educational psychology can be divided into three main groups :

- (1) Detection of backward children, which is often the beginning of diagnosis and treatment of various difficulties in adaptation ;
- (2) Educational guidance involving the testing and adaptation of educational methods ;
- (3) Pre-vocational guidance.³

It can be suitably suggested that a network of school psychologists extending all over the country should be created. The tasks like the following can be conveniently taken up by those trained in this field :

- (1) The examination of children who have adjustment difficulties ;
- (2) The examination of children who cannot follow the normal school programme ;
- (3) Information service for parents and teachers ;
- (4) Planning, creation and standardisations of new test batteries ;
- (5) The scientific treatment of the material collected.

A glance at the recommendations of the Mudaliar Commission's Report on Secondary Education will convince that there is a great need for school psychologists. The proposed diversified curriculum, better facilities for guidance and counselling, replacement of examination by better methods, introduction of cumulative record cards, the use of tests and similar reforms will need the services of psychologists in schools. There certainly is a future for those who wish to specialise as school psychologists.

(b) *Industrial Psychology* : Although at present there are not many psychologists in Indian industries, their number can be counted up on finger tips, we can reasonably expect that there shall be an improvement in this situation. In U.S.A. the psychologists are employed into three broad areas—(1) business and industry group, (2) consulting group, (3) advertising group. The titles of the 65 per cent. of the business and industry group denote technical, personal and top-executive functions. The remainder have titles such as testing administrator, personnel and research assistant, personnel statistician and employment psychologists ; their work being duties involving personnel functions, scientific research and development functions, policy and management functions, labour relations functions.⁴ This information gives a clue to the possibilities of employment of psychologists in industry. Moreover, the importance of the human element in the efforts to improve productivity need hardly be stressed. There are some problems in which the human element is directly involved—viz., problems relating to the attitudes and outlook of the workers and the management, labour-management relations, methods of recruitment, training and promotion of personnel, work incentive, welfare facilities and health and safety arrangements. To quote R. M. Bellows, "Lack of human understanding is commonplace among personnel in any organisation. Social distance between management and worker increases more and more as size and specialisation in industry increases. This is a serious problem in present-day industrial civilisation. The solution lies in a planned study of the problem from the viewpoint of industrial social

³ UNESCO : School Psychologists.

⁴ Canter R. R. : Psychologists in Industry.

psychology and the development of techniques of sociometry and communication''.⁵

For a successful application of psychology in industry, our psychologists shall have to know not only psychology but shall have also to gain acquaintance at least with some specific aspects of industry in order to be effective and to be an asset. This will mean a change in our training programmes in the universities; our programmes shall have to include industrial matters. If we wish that psychologists should be employed in industry, our courses of study will have to undergo a drastic change. For a reference, I may be allowed to draw attention to the experience of Graduate Training in Industrial Psychology at Purdue University in which the following aspects find a place: training in personnel problems, job analysis, testing techniques, methods of increasing work efficiency, incentive and morale, also training in statistics and familiarity with clinical, experimental and educational psychology.⁶

(c) *Counselling Psychology*: Our most important resource for successful planning is our man-power and the psychologists can play a significant part in helping to develop this resource. It is, indeed, true to say that people have problems and counselling is intended as an aid in the solution of those problems. Counselling services are rapidly developing all over the world. A large number of psychologists are engaged in counselling in schools, in business, governmental, social services and industrial situations. This is an expanding field for our psychologists because business and industrial organisations seem to be interested in improving quality and quantity of production by promoting better human adjustment. "The perplexing problems of to-day and to-morrow can be more readily solved if the individuals who are called upon to deal with them do not have problems of their own which often prevent their maximum functioning. Counselling is the solution to an individual's problems."⁷

This field is likely to attract people other than psychologists and that is why it is absolutely necessary for us to be careful. At the outset there is likelihood of some confusion about the distinction between clinical and counselling psychology. But there can be no doubt about the fact that the work of counselling should be based upon psychological knowledge and that a sound programme of training is necessary for those who are to occupy positions as counsellors. The duties of a counsellor are so varied that a counsellor should be broadly trained and must be more than a psychologist. Shartle has described how a counsellor is often known by other names like College Counsellor, Psychologist for physically handicapped, Consulting Psychologist, Employment Interviewer, Employment Counsellor and Vocational Counsellor. Considering these, a report for the Counsellor Training Committee to the Division of Counselling and Guidance of the American Psychological Association recommends that all counsellors should receive training in each of the following areas of psychological study:

- (1) The foundations of psychology, including an overview of the various fields of psychological study.
- (2) The psychology of growth and development with special emphasis on the age group to be served by the counsellor.

⁵ Roger M. Ballows : *Psychology of Personnel in Business and Industry*.

⁶ Tiffin S. and C. H. Lawshe : *Graduate Training in Industrial Psychology at Purdue University*.

⁷ M. L. Blum & B. Balinsky : *Counselling and Psychology*.

- (3) Nature of individual differences, and the implications of these differences for counselling.
- (4) Principles of learning and their application in education and other pertinent situations.
- (5) Personality development and mental hygiene.
- (6) Psychological tools and techniques for the study of individuals and diagnosis of their problems including tests and other procedures.
- (7) Principles and procedures of counselling.
- (8) Supervised practice in diagnosis and counselling.
- (9) Statistics and research methods used in those psychological investigations ordinarily used or undertaken by all counsellors.*

I have sketched three fields which I consider propitious for healthy advancement of psychology as a profession in this country. If such a progress could be made, we shall have in the near future many more problems worthwhile for discussion and controversy about psychology as a profession. For the present our aim should be to establish the independence of the profession of psychology in this country ; and for that purpose it is urgent to examine the related fields of teaching and research.

III

Teaching of Psychology : Courses of study in psychology shall play a significant role in fostering the growth of psychology as a profession. In our courses of study, we tend to divide our subject into a number of divisions. These divisions are needed because numerous sciences have contributed to the man's understanding of man, also it is a complex study ; the divisions help us to solve the administrative problem of distribution of work among the members of the staff.

But while devising courses of study we should neither forget, nor play down, the basic unity of psychology as a field of knowledge and practice. The instruction can be imparted either piece-meal or by a contextual method. Really speaking, a student is required to explore six relations :

- (1) Influence of Body on Mind
- (2) Influence of Mind on Body
- (3) Influence of Environment on Mind
- (4) Influence of Mind on Environment
- (5) Influence of Environment on Body
- (6) Influence of Body on Environment

The study of these relations is quite complex and we can clarify the complexity by regarding each as having 'five' dimensions, viz., Space, Time, Quantity, Quality, Significance.

There are two facts which have added to our difficulties in organising courses of study. First of all, Psychology has a richness of affiliations both with the other branches of knowledge and with the whole practical field of human relations. And secondly, there is a personal limitation of the teacher, of even the great and noble teachers, to concentrate on certain issues or aspects which appeal to them at the expense of other important issues. This indicates the need for building up a common ground on

* Froehlich C. P. : Content of the Manual on Counsellor Preparation.

which the majority of professional psychologists must need base their work.

Keeping these points before us, we can suitably study the methods which are adopted to divide the courses of study in suitable branches and units. The whole science can be divided into two main branches : (1) Theoretical Psychology to impart a knowledge of basic concepts of leading schools of psychology like psycho-analysis, gestalt, etc. ; (2) Empirical Psychology to impart a knowledge of techniques to find facts like laboratory experiment, psycho-metrics, mental testing, interviews, social field work, clinical observation, etc., or we can arrive at divisions according to the affiliations of psychology with other subjects as : (1) Psychophysics, (2) Bio-Psychology—Physiological Psychology and Neuro Psychology, (3) Animal Psychology, (4) Philosophical Psychology. To these divisions, we can suitably add a group of studies to be known as Applied Psychology like (1) Clinical Psychology which will be a group of overlapping applications like Psycho-Therapy, Psychiatry, Psychological Medicine, Psycho-analysis, Child Guidance, Play Therapy, Occupational Therapy, Psycho-pathology, etc. (2) Educational psychology including Child Psychology, (3) Social Psychology which will extensively use the information from sciences of Sociology and Social Anthropology also the psychological study of institutions and collective psycho-pathology such as crime and war, (4) Occupational Psychology which will be the study of human beings at work.

We can systematize courses of study by adopting a three-fold method of division. There are branches that deal with the methods of arriving at psychological facts by experiment or observation and also give us methods of practical action or treatment ; there are others which give us theoretical ideas and explanations and give us the basic conceptions ; there are branches that deal with facts or theories concerning normal individuals and the others that deal with the abnormal phenomena. Whichever method we adopt, our goal should be to prepare men to build up psychology as a profession.

IV

Research in Psychology and Educational Sciences : Dr. H. J. Eysenck has observed that research, in order to be fruitful, "has to be what Marquis (1948) has called 'programme research'. In other words, research has to be planned for a whole department around a common objective, it has to be continued over a period of years and the research activities of students and teachers alike have to be integrated into it. Only in this way can one hope to avoid the inconclusive outcome which all too often characterises the individual short-term research.

Individual students, of course, must be free to choose whether they want to take part in the departmental research, or whether they want to strike out for themselves ; it is our experience that the majority welcome the opportunity of making an active contribution to the development of a programme which shows promise of furthering our knowledge of human nature. Such training will also prepare the student for the type of team research which is becoming more and more prevalent in the social field, where specialists in many disciplines must collaborate in order to solve a problem common to them all."

* H. J. Eysenck : *The Scientific Study of Personality*.

It is, indeed, true to say that in our age scientific research in general is moving towards an era of the planned collective expedition from an era of individual exploration. The isolationism in research to-day is as badly dated as isolationism in politics. I am quite aware that this may be challenged; the individualists amongst us may deplore this diminishing of the scope for the lone research worker's intellectual curiosity but if we are realists, we should recognise that this tendency is inevitable in a world which is daily growing more complex and thus difficult for individual efforts. The lonely cloistered sterility of academic departments needs to be replaced by a vigorous family life.

Secondly, it can usefully be suggested that there is a need to formulate a philosophy of research. This may appear, in the first instance, to be a contradiction because science seems to have advanced most gloriously whenever it has been most defiant of philosophy. When a man embarks on research, he is breaking new ground. Should he not, therefore, face his exploration with completely an open mind, prepared for anything? This would, at any rate, appear to be true to common sense. But it is false in fact and false in principle. A research worker never faces his exploration with an open mind; the very fact that he is setting out in a certain direction, closes his mind to the other possibilities which may be incompatible with that direction. Nobody takes up an exploration without a motive; there is always some reason good enough for a research worker that decides the course of research. In fact this can be neatly expressed in a paradox that "the research worker always knows more about the unknown than he admits but he does not know that he knows it".¹⁰

We are going through a period of planning; it is, indeed, a critical, transitional and formative epoch in our national life bristling with problems; and as all problems cannot be solved at once, there is a need for research on an unprecedented scale; and also a need for a change in outlook. The research methods in the past were thought out in terms of single workers, undertaking specifically defined inquiries. There was an already formulated problem and the research worker satisfied his conscience by paying close attention to the details of the method.

When a person says, "let me do research," he is saying, "let me be scientific". Now it is an interesting contemporary fact that the majority of our professors of psychology and of education in this country seem to have their academic ground work in the Faculty of Arts. And since this is a fact—and do not the scientists respect facts?—it will not be scientific to fritter away energy in dreaming about how wonderful education or psychology would be if only all our professors of psychology and of education were scientists? It is clear, therefore, that a significant and large scale research will be achieved only through a true marriage of Arts and Science. This leads me to formulate that any effective research must have four aspects:—Philosophy, Strategy, Tactics and Techniques. Philosophy is the thought and imagination and discussion which determine which problems are fundamental; the strategy is the long term organisation of researches to establish a new and coherent body of knowledge related to a fundamental problem; the tactics are the activities necessary to secure the data and the techniques are the detailed procedures for obtaining, analysing and interpreting the data of the problem.

For us it is becoming necessary to formulate a worth while strategy of research. Of course, there cannot be a formula for successful research

¹⁰ G. P. Meredith: Departmental Notes: Leeds. (Unpublished Notes of Dr. G. P. Meredith are gratefully made use of for some of the points in this section.)

as research by its very nature is unique. There can be standardised procedures for surveys or statistical methods for handling the tables of test results. These are necessary and the training in the use of techniques is needed. But does the real interest of a research worker lie in the use of procedure or in the element of novelty? Can we encourage research by simply offering a training in standardised techniques, leaving the essential problem of dealing with the unique and the novel to the research workers? This is extremely difficult to answer ; it is certain that we need something more than mere making of technicians. Therefore, the research should not be taken up as a mere spare time pursuit ; the individual research worker should not work in isolation as in the past. We cannot and should not remain content with individualistic muddling through and therefore, a worth while strategy needs to be evolved by collective decision.

In this context it is desirable that our research deliberately and proudly arises out of local needs and provides local solutions. This proposal may be challenged because of a belief that research should aim at the truth with a capital T. May I ask, is there one truth for Uttar Pradesh and a different truth for Bombay? To quote Prof. G. P. Meredith, "I think much educational and psychological research hitherto has led to fallacious thought and unsound practice through a misplaced faith in its universality. Certainly Universality is the aim of all scientific research but the more complex the subject-matter the deeper we have to dig in order to reach its universal foundations. In other words the more circumpsect we must be in making generalisations. Physics and Chemistry alone are universal among the empirical sciences. Geology has certain universal features but it has developed most successfully by close attention to local detail. The extreme variability of living creatures revealed by Biology shows the importance of local studies in this field. And in the science of Man we have to deal not only with a creature of supreme individuality but with a creature more responsive than any other to local influences. The misguided enthusiasm for statistics found in certain types of research workers leads them to treat men as indistinguishable atoms and to make deductions which may be true of the figures but which are not true of the facts. The mean and the dispersion of the I.Q. is a case in point. For the nation as a whole these may be, say, 100 and 15 respectively but these may not be exactly true for any single limited locality". The research like charity should begin at home. Most of our problems are problems arising in a local context, *e.g.* the problem of indiscipline among students. We may attempt to find out solutions which may be applicable anywhere, but solutions should work first here ; and in that process, it is possible that we may hit upon a finding which may be of national significance.

Due to the prevailing circumstances in our country research opportunities have been limited in many respects and frequently the choice of problems to be studied has of necessity been affected by this fact. We, therefore, need group collaboration for a division of labour so essential if the diversity of talents is to be appropriately applied to the diversity of aspects in any research ; secondly, a close scrutiny of the problems is necessary so that the problems studied are real and important problems.

V

It has been suggested in the course of this discussion that there is a need for all of us to develop psychology as a profession. The plan for the development of our subject should reflect the current trends in psychology

in the twentieth century. We are at a great advantage as the usefulness of psychology is being gradually recognised all over the country. We should, therefore, be able to develop it along sound scientific lines, which may prove socially useful to lead the country on paths of prosperity and progress. It will, indeed, be possible for us to develop a vigorous profession that will recognise social responsibilities through various types of services that will be rendered by our members.

Through this discussion we can now arrive at the following conclusions :

- (1) At present there are not many school psychologists except in some larger towns hence a network of school psychologists extending all over the country should be created ;
- (2) It is also necessary to build up a close relationship between psychology and industry by providing industries with well-trained psychologists ;
- (3) To assist both the rural and urban areas, it is necessary to make available the services of trained psychologists who may work as counsellors ;
- (4) The present system of the training of psychologists needs to be reviewed and improved ;
- (5) The planned collective research should be preferred to isolated research work.

It will be easy to agree with Sir Cyril Burt that "Applied psychology has already begun to influence our everyday life" and that "if the same amount of time, money, and ability is now devoted to psychology as has hitherto been devoted to physical science, still more rapid progress will be achieved".¹¹ In all different fields of psychological work, strong expansive tendencies are to be discerned ; it is undoubtedly true that the hard economic conditions since the war have hampered development everywhere, but fortunately we can conclude safely on an optimistic note that with the progress of our Five Year Plans, the significance of psychology will be recognised in India to the same extent as it has already been recognised in many larger countries.

And for this purpose, we shall have to do a number of things. One of the steps which needs to be taken at the outset by each Department of Psychology in our Universities is to review carefully the facilities for study and the staff situation. It will be meaningless to introduce students to this subject without proper facilities for study and experiment and well-trained staff. Moreover, it would be advisable for each Department of Psychology to develop and concentrate on one or two specialities—and even discontinue those for which facilities may not be adequate.

Prof. Carl R. Rogers has recently commented that "the general climate of American Psychology today does a great deal to discourage original and creative thinking."¹² Does this remark not give us a valuable hint? And if it sounds valuable, is it not serious? We have imported to a very large extent the theories of Freud, Pavlov, Binet, McDougall, Spearman, Thomson and others ; the time has arrived when we should develop the home market. Has not the time come for our Departments of Psychology in Indian Universities to develop Indian Psychology? Prof. Rogers remarks :

¹¹ Sir Cyril Burt : Psychology (Scientific Thought in the Twentieth Century).

¹² Carl R. Rogers : A Personal View of Some Issues Facing Psychologists (The American Psychologist, June 1955).

"We have drawn our creative hunches and theories from European Psychologists, and have been content to use our technical skill to develop, confirm and apply, or to oppose and refute, those ideas. It is instructive to contemplate what American Psychology would have been without the contributions of Freud, Pavlov, Binet, Kohler, Koffka, Lewin, Spearman, and the like. But it is highly unlikely that we can continue to import creativity. We must develop the home-grown variety, and I fear we do very poorly at it. As psychologists, we know all about theories. We can tell a hypothetical construct from an intervening variable. We know a molar theory from a molecular, we can expatiate on the difference between phenomenalism and introspectionism. But with all this learning, very few American psychologists construct theories. We know all about research methods, and are, by and large, decidedly rigorous research technicians. But we tend to utilize our methodological skill in attacking "safe" and conventional problems. We appear to have a real fear of grappling with the new and unconventional. It seems too often true that we can analyse but not construct, criticize but not build, categorize but not create." These remarks are, indeed, thought provoking ; we should be aware of our sources of strength and weaknesses, our wisdom and limitations. Let us, therefore, build Indian Psychology on scientific lines ; let us grow on our own lines ; let us export some fresh approach to the subject. There is no doubt about society's demand for psychologists ; that demand should be made increasingly strong in the interest of our profession. I hope the two important problems viz. to achieve recognition for our men and to develop it as a field will soon be solved by our joint endeavour, and we shall be able to state boldly that Psychology as a profession has arrived.

SECTION OF ENGINEERING & METALLURGY

President :—DR. BIRENDRA NATH DEY, D.Sc. Eng'g (Glas.),
M.I.E. (Ind.), &c.

PRESIDENTIAL ADDRESS

NEW OUTLOOK IN A NEW AGE

We meet here today at a turning stage in the engineering history of the world. The very basis of engineering, viz. power-production, is undergoing a fundamental change.

The largest international scientific conference in history held last August at Geneva marked the year 1955 as the milestone and starting point of a New Age and recorded the revolutionary evolution of a new source of energy—the atomic energy—for power engineering.

Contemporaneously, Asia's New Age is growing and developing in the lands of her leaders—China and India.

The need for a new outlook has thus arisen for the engineers and scientists to meet the new demand.

I have had a glimpse of this new outlook among the Chinese engineers and scientists during my tour of China last summer, at the instance of the All-China Federation of Scientific and Engineering Societies who invited me as a representative Indian Engineer to visit that country.

The strictly indigenous language medium for science and engineering adopted by China is a pointer for India to emulate. This is quite normal and usual in the countries of Europe who are in the vanguard of scientific progress, but not so in the Asian countries who lag behind.

Before dealing with the new sources for power-production and other matters, I would like to say something about the role of engineering and engineers in the Indian Science Congress.

This is the 16th session of this Section of the Indian Science Congress who, however, are meeting for the 43rd time. This is due to the belated inauguration of this Section of Engineering within the framework of the Indian Science Congress, whose organisers, nevertheless recognised the importance of engineering as early as 1923.

In that year, 1923, the tenth session of the Indian Science Congress was held at Lucknow. The doyen of Indian Engineers, Bharatratna Mokshagundam Visvesvaraya adorned the Chair of the General President at that session. This event proved the genuine desire of the organisers of the Indian Science Congress Association to honour the engineering profession. Following the exhortation of Visvesvaraya, this Section of Engineering at last materialised and we are now in the 16th session.

In allocating a separate Section to Engineering, however, an important subject—Metallurgy—has been tagged to Engineering. The consensus of opinion, which I also share, is that an exclusive section should be set apart for such a vast subject like Engineering. For, unlike any other branch of applied science, Engineering has developed into the art and science of total human operation on the material resources along pre-determined lines to reach pre-calculated objectives, and has brought about a revolutionary development in human efforts at making more and more out of the natural forces, by a unique combination of functional science and operational art.

I feel tempted to quote here a few lines from the very pertinent pronouncements of Visvesvaraya on the platform of this Indian Science Congress of 1923 urging the Indian Nation then in bondage and slumber to realise that no nation can survive if it neglects science. He then referred to the First World War “under the stress of which invention followed invention with astonishing rapidity either for stimulating production or for increasing the effectiveness of offence or defence”. He then pointed out that “technical education is confined to an infinitesimal proportion of the population. The alumni of our universities lack the freshness of touch which contact with live problems gives, and our intelligentsia have few opportunities of becoming familiar with new inventions till long after they have ceased to be novelties in the outer world”.

A third of a century has elapsed since the above declaration of Visvesvaraya. Another Great War by far greater in magnitude and intensity has also taken place in the interval, in the course of which invention followed invention with more astonishing rapidity. But how far India has progressed and where she stands now in the context of world progress in science and engineering?

Undoubtedly some progress has been made. But our academies and institutions still lack the freshness which contact with live problems gives. Our intelligentsia are yet to be adequately familiar with new inventions. And, as for the larger section of the population, I don't think I need tell you how far behind they are in the backwaters of the world currents of science and engineering.

THE NEW AGE

When India thus stands on the weak link of the world chain of science and engineering, a New Age has dawned on us, imperceptibly but decisively. A new knowledge of Power at the disposal of man features the fundamentals of this New Age.

If gun-powder brought about the great Renaissance in human thought—the world till then labouring under medieval immaturity, if the steam-engine ushered in what we call the age of mechanical civilisation, if the internal combustion engine with turbines and jets have attributed newer values to the known dimensions of space and time, the new knowledge about our familiar Atom is thrusting upon us a new era of Power Science, and with it, a new era of Power Engineering.

Talking of atomic energy, the subject has not been unfamiliar with us for the last few years. We have often heard how the more or less mathematical propositions about creation of a “Brave New World” upon the tiny atom could someday be worked out into reality.

That this someday is here has been unreservedly revealed in history's largest scientific conference held last August in Geneva in an atmosphere of international co-operation. Over 2,000 scientists from different parts of the world, more specially, from rival lands, met and discussed the ways

of mastering the jinn created by atomic fission and harnessing him for the benefit of mankind. In this conference were presented the results of their work which had been so far guarded as iron-clad secrets.

That Conference reached the momentous conclusion that the destiny of man is bound up with the atom. If he must survive he must learn to control the tremendous forces hidden in it and use them to his benefit. For, the World whose population is multiplying rapidly and whose conventional sources of energy are being exhausted, will soon be faced with a scarcity of fuel. Physicists have reckoned that in A.D. 2000, it will need eight times as much energy as it is used now. The problem, therefore, is not as remote as the layman might imagine.

ATOMIC ENERGY

As pointed out by our Dr. H. J. Bhabha in his presidential address to the afore-mentioned Geneva Conference, "atomic energy could first provide the energy necessary to enable the under-developed countries to reach the standard of living of the industrialised countries and, secondly, enable the entire world to maintain a constantly rising standard of living for very many decades and possibly for several centuries."

The point is of immediate importance to India, for she would exhaust her coal reserves in about ten years if she were to consume energy at the same rate as, say, the United States of America. India's potential hydro-electric capacity is said to be about 35 million K.W. and this would be exhausted in the succeeding decades. Nuclear energy would thus have a specific role to play in areas where hydro-electric development was likely to be slow through being combined with irrigation plans requiring large investment, as well as in other areas where cost of coal transportation was very high to preclude thermal stations.

It has already been reported in the Indian Press that nationalisation of the coal mines does not now feature among the possibilities in the Government of India's official plans. The Government of India, it is said, has to keep in view the possibility that, with the development of atomic energy, the importance of coal may decline perceptibly within the next ten years.

Again, during the last September session of the West Bengal Legislative Assembly, the Chief Minister Dr. B. C. Roy reminded the House of the profound change taking place in the world today, and said that it was quite possible that in the next ten years or so they could have an atomic reactor for production of electric power at a much cheaper cost than coal. This consideration, Dr. Roy pointed out, was to be kept in mind in deciding the question of nationalising such an undertaking as the Calcutta Electric Supply Corporation.

It has also been reported, that India's first atomic reactor will be constructed during this year under an atomic programme following United Nations action setting up an international agency for peaceful development of atomic energy. A processing plant will extract uranium and thorium from the monazite sands of Travancore.

Extensive atomic power stations projects have been planned in Russia and America (U.S.A.), the two leading big countries of the world, who have already some stations in use. Even in an otherwise small country like Britain, atomic power is claimed to have attained eighth place among her top dozen industries. By 1975, Britain expects nuclear power doing the work of at least 40 million tons of coal a year, through 12 or more nuclear power stations.

Some foreign countries even contemplate exporting nuclear power stations for generation of electricity to those areas of the world where generation by other means might be difficult or more expensive. It is said that the price of these exported stations should be comparable with existing prices of electricity generated by conventional means. For export, compact nuclear reactors called "package reactors" are being designed, whose component parts could be dis-assembled, "packaged" and flown to distant and remote parts of the world.

The great advantage of atomic power stations over conventional types is that they need none of the auxiliary services such as railways, roads and geological surveys. The main basis of these stations is that they will be small reactors and will be scattered over the country.

At Geneva was exhibited an atomic power station model. It has three nuclear reactor "furnaces" in which uranium is "burnt", each one of which has six heat exchanger units ranged close alongside its outer radiation-proof casing. Inside these heat exchanger units the gas—which is pumped through the reactor furnaces to draw off the heat generated as the uranium is "burnt"—is used to heat the steam-raising water for the electricity generating plant. The generating equipment together with the blowers, which force the carbon dioxide through the reactors and the heat exchangers, was housed in a covered building on one side of the row of "furnaces". A pond for storing the dangerously radio-active slugs of uranium fuel (as they are ejected from the reactors) ran along directly beside the reactors.

One need not worry about the waste disposal of fission products. These fission products are processed and stored at chemical processing factories under control away from the nuclear power plants. As mentioned before, atomic power reactors would be scattered throughout the country but the chemical processing of irradiated fuel elements would have to be strictly confined to one or two centralised chemical factories. Besides, more and more use is being found for these fission products in industry and medicine.

Some leading geneticists at Geneva gave the warning that atomic radiation as a result of the world-wide use of nuclear energy might be hazardous to future generations. But Sir Christopher Hinton, head of Britain's Atomic Energy Authority (Industrial Group) quite confidently declared that "on the industrial side there is no reason why a well managed atomic programme on a large scale cannot be set up and operated under conditions that will be entirely safe and cause not the slightest concern to geneticists."

According to Dr. A. A. Latavet of Soviet Russia, a shorter working day and longer paid holiday are among the ways of protecting the health of atomic workers in addition to technical measures (e.g. ventilation) aimed at the further reduction of the dose of radiation at the place of work. All the main atomic enterprises in Russia have strict sets of rules and non-observance of these resulted in a fine and even court action in cases of gross violation.

Atomic Energy Plants in Russia and United States of America had remarkable safety records. With more and more intensive research all possible risks and hazards will be eliminated and overcome.

Concluding this brief review of the far-reaching power-potentials of atomic energy, I have no hesitation in endorsing the prognosis made by the engineers and scientists at the Geneva Conference that the thermo-nuclear age will transform the world in a more radical manner than the Industrial Revolution of nineteenth-century Europe.

SOLAR ENERGY

Another great source of energy, which is going to bring about a phenomenal change in our conventional approach to power engineering, is that all-pervading source, the SUN. For sometime now man has tried to tap this master source of incessant energy, to store it, to find direct application for it by mechanical means.

The recent progress in harnessing the solar energy is quite encouraging. Just what is being accomplished in their effort in this sphere by scientists throughout the world has been reported by the well-known Stanford Research Institute of America, which has produced an illuminating compilation of progress so far made towards harnessing energy from the sun's rays.

Each day, according to these reports, the sun sends more energy to this planet than man uses whether its source be coal, oil, atomic reactors, or hydro-electric generators. On the roof of every house in the United States for example, the sun showers 100 times more energy in 12 hours of daylight than the occupants of the house can use for all their requirements including even two television sets. Further, the rays of the sun reflected from Lake Mead, formed by Hoover Dam on the Colorado River, contain more energy than the generators in the dam turn out.

Sunlight, as is known, is a wave of energy. It is similar to an alternating current, a radio or television pulsating-beam, or X-ray. One way to understand the energy potential of sunlight is to visualise a ray of Sun as a stream of tiny bullets of different sizes. Solar energy capture involves putting to work the various ways individual molecules of matter respond when hit by the 'sun-bullets'.

An example of how this solar energy may be put to work on a minute scale—but none-the-less involving the transformation of sunlight into electrical energy—is the common photo-electric cell light meter used by photographers to measure the strength of light for their snap-shots. The instrument is held towards the Sun. The light striking the photo-electric cell generates a minute charge of electricity. This energy, in turn, moves a needle which quivers across a dial, stops, and gives the 'meter reading' for the picture.

But this principle has yet to be applied on a scale which will turn sunlight into sufficient energy to operate an engine. It is however encouraging to learn that the research so far has disclosed five ways of capturing solar energy, which may be practical:—

- (1) *Radiation reflection.* This involves the use of a mirror to change the direction of the sun photons.
- (2) *Molecule Motion.* This involves the conversion of sunlight to heat. One device used is a flat-plate collector consisting of one or more layers of glass or other transparent material placed over a heat-absorbing substance. This principle can be used in solar-stills or home heating systems.
- (3) *Electron disturbance.* This method is related to phosphorescence, a means of briefly storing light energy. There are some limited applications of this method, but it is not yet regarded as a major energy-producing device.
- (4) *Electron removal.* When atoms of certain molecules are hit hard enough, some of the electrons are jolted entirely from their orbits and away from the parent atom. Once out in the open they create an electric potential which causes a direct current of electricity, the method used by the photographer's light-

meter. But this method is inefficient for general usage because it converts only about two-tenths of one per cent of the received light into electric energy.

- (5) *Molecule re-arrangement.* The best known reaction of this method is the use of solar radiation of chlorophyll to convert water and carbon-dioxide into carbo-hydrates and oxygen. But how the plant chlorophyll is able to use solar energy for this purpose is one of the things which scientists are still trying to find out.

The use of the sun-energy to rupture water molecules is promising. The possibilities on this score justify major research efforts. Hydrogen, one of the elements of water, can be stored conveniently as a gas and the energy recovered by burning, release of heat, and the formation of water.

I have no doubt the attack on the problem will gain momentum. The success of the efforts of the scientific workers in this direction is almost mandatory because of the need for new forms of energy.

For the same equally vital reason, scientists and engineers should continue with more intense pursuit their endeavour to wring workable methods of efficient harnessing of energy from other non-conventional resources like :—

- (a) Cosmic Rays.
- (b) Heat stored in the Earth (having surface indications like volcanic eruption, hot springs, &c.).
- (c) Tides (caused by the diurnal rotation of the earth about its own axis under gravitational attraction of the Sun and the Moon).
- (d) Winds.

THE ROLE OF ENGINEERS

While I trust the engineers and scientists to investigate deeply into the problems of harnessing the energy from the afore-said non-conventional resources, I am sure they would go on working for getting larger quantum of mechanical energy from the established conventional sources. It is gratifying that the research workers are busy throughout the world along this direction.

It is equally satisfying that no Government in any part of the world, irrespective of its socio-political character, has failed to recognise the importance of scientific and engineering research being directed along lines of production or conservation of mechanical energy both from the conventional and non-conventional resources.

The engineers come in the picture, as they are necessarily to be called upon to work with all the mechanical energy at the disposal of a nation. As ever and now, with less or more mechanical energy, whether it is planning of a low-cost housing scheme or the building of a sky-scraper, the designing of an improved plough or the working of an atomic reactor, the engineer is everywhere. An engineer is a planner, a designer, an erector and at the same time a watchful supervisor of his own performance. He is all through a working element—a functioning unit of human material in every inch of an operation, precisely knowing why or how of it and with what or on what to perform.

The problems of the engineering profession are complex and manifold. Equally complex and manifold are the worries and anxieties of the working engineer throughout the world. War or no war, non-stop and with all devotion he goes on wielding his brains and brawn. He works with the people and he works for the people.

The Indian Engineer is much fortunate in that the leaders of the nation have neither defaulted nor have been slow to recognise the merits of his services in the all-out effort at re-building the country. The Indian Engineer is fortunate too, for, he has to work for a genuinely peace-loving and tolerant nation. With the advent of freedom and after liberation, the Indian nation is on the move and is quick in responding to world trends. India today thus offers to her engineer the most receptive virgin soil for his art and science to have a wide play. The engineer in India has much reason to be hopeful, ambitious and even aspirant.

NEW OUTLOOK AND NEW APPROACH

Keeping in mind the huge requirements of the New Age of Power Science and Power Engineering, I strongly feel that for lasting and effective solution, the national reconstruction problems facing our country require indigenous materials, indigenous methods and indigenous talent.

Also required is indigenous thinking, not the copy-book thinking imported from abroad and implanted here. We have had enough of borrowed materials, borrowed methods, borrowed talent and even borrowed thinking during the days of colonial rule. This "colonialism" in the sphere of engineering and science must go. A radical break from the fossilised traditional rut, from the rooted mental fixations is necessary, and, I should say, mandatory upon the scientists and engineers in our New India in the making.

That is why I was elated to hear that India had made "an extremely important" contribution to the archives of world knowledge with valuable disclosures on zirconium, a most important metal used in atomic reactors on a commercial scale. India revealed at Geneva a new method of separating zirconium from its chemical cousin hafnium to obtain the pure metal. So long hafnium was used as a regulating element for security in reactors ; separating it was extremely difficult and costly. The new process evolved by Indian Scientists is a departure from "traditional methods" of separation using the readily available and inexpensive chlorine.

Here, let me tell you, that I felt similarly elated, during my recent visit to China, when I was told that Chinese experts had invented by original and indigenous methods an economic process in the manufacture of synthetic petrol through the discovery by them of a new catalytic agent in place of the costly cobalt.

This is the correct approach. Like China, India must learn to liberate herself from the still-persisting colonialism in science and engineering as she has done in other cultural spheres.

A new approach to the whole question of Training and Research is thus necessary. India must direct her active thoughts to remodelling the existing pattern of engineering education and operational research. The nation demands a new outlook to effectively cope with the requirements of the new age.

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